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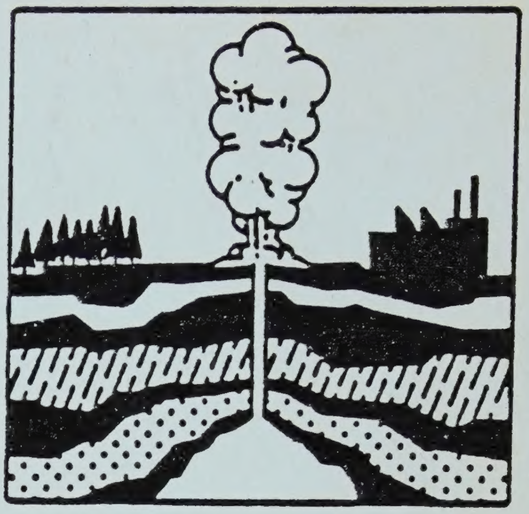
GEOTHERMAL ELEMENT



TO THE SISKIYOU COUNTY GENERAL PLAN

ELIOT ALLEN & ASSOCIATES INC.

May, 1984

GEOTHERMAL ELEMENT
to the
SISKIYOU COUNTY GENERAL PLAN

May, 1984

Prepared for
Siskiyou County, California
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Salem, Oregon

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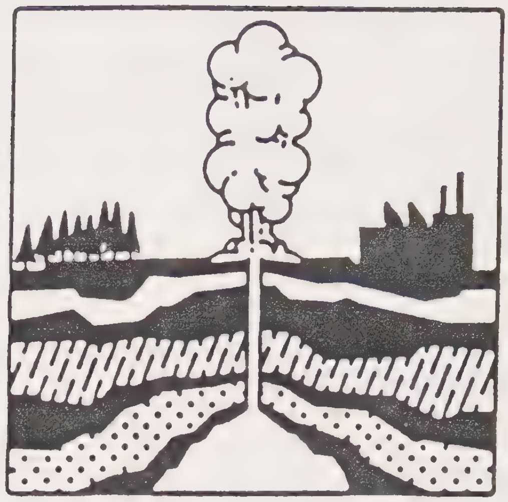


INTRODUCTION

Objectives of the Geothermal Element

Siskiyou County has had a known geothermal energy potential since the earliest days of its settlement, with volcanic geology, hot springs, and warm wells offering clear evidence of the heat lying beneath the earth's surface. In recent years the increasing value of renewable energy has brought about increased interest in Siskiyou County's geothermal resources. Today, County residents are heating homes and businesses with low-temperature resources, and industry is exploring for high-temperature resources capable of generating electricity.

In response, the County commissioned the preparation of a Geothermal Element for its General Plan in 1983. The adoption of a Geothermal Element is an option which California counties have when faced with significant geothermal development potentials.

A Geothermal Element to the General Plan is defined by California statute as "an element consisting of a statement of geothermal development policies, including a diagram or diagrams and text setting forth objectives, principles, standards, and planned proposals, including a discussion of environmental issues and identification of sensitive environmental areas, including unique wildlife habitat, scenic, residential, and recreational areas..." (Public Resource Code Section 25133).

Aside from these State parameters, Siskiyou County's Geothermal Element has been prepared so as to accomplish the following objectives:

- Completion of a County-wide assessment of low- and moderate-temperature resources.

- Identification of feasible applications for low- and moderate-temperature resources.

- Evaluation of the prospects for high-temperature resource development.

- Identification of local, state, and federal interests in the resource, and resulting coordination and regulatory needs.

- Establishment of County policies and implementation measures for guiding resource development and utilization.

Given the relatively early stages of geothermal development in Siskiyou County, an overriding purpose of the Geothermal Element is to serve as an informational tool for citizens and local officials who are becoming familiar with the concepts and potentials of geothermal energy. As geothermal development occurs within the County it is expected that the Geothermal

Element will be amended to expand from an educational focus to include more specific development guidelines.

Geothermal Energy Defined

California defines geothermal energy as:

> ". . . the natural heat of the earth, the energy, in whatever form, below the surface of the earth present in, resulting from, or created by, or which may be extracted from, such natural heat, and all minerals in solution or other products obtained from naturally heated fluids, brines, associated gases and steam, in whatever form, found below the surface of the earth, but excluding oil, hydrocarbon gas or other hydrocarbon substances." (Public Resources Code, Chapter 4, Division 3, Section 3701)

This is a comprehensive definition designed to cover all possible energy and mineral resources that are directly or indirectly related to, or produced by, the natural heat of the earth. For purposes of Siskiyou County's interests the definition will be restricted somewhat to include only that energy that is in the form of heat, and that is contained in and can be economically extracted from naturally occurring subsurface water and/or steam. Using this definition, a geothermal resource would include any subsurface water (ground water) or steam that could be economically developed in order to derive some benefit from the utilization of its thermal characteristics.

Geothermal resources are commonly categorized by temperature range. The ranges of these temperatures are subject to various interpretations. The U.S. Geological Survey (USGS) classifies

low-temperature resources as those less than 194°F, moderate-temperatures as being between 194°F and 302°F, with high-temperatures occurring above 302°F. The State of California, on the other hand, considers any geothermal resource that is at a temperature less than the boiling point of water at the altitude of occurrence to be a low-temperature resource, and any resource above that temperature to be a high-temperature resource. Like the USGS, the State sets no lower limit for low-temperature resources.

For purposes of Siskiyou County's Geothermal Element, low-temperature resources shall be considered to be any economically developable ground water with temperatures between 40°F and 120°F. The lower limit of 40°F is chosen because water source heat pumps generally do not operate efficiently below this temperature; alternately, 120°F represents the general upper limit for heat pump applications. Moderate-temperature resources shall include water with temperatures between 120°F and the boiling point at the altitude of occurrence. This range is selected because it represents resources that can generally be used directly in an end-use. Resources with temperatures exceeding the boiling point at the altitude of occurrence are considered to be high-temperature in nature, and generally suitable for power generation.

It is important to note that these categories are not absolute, and that, in fact, some applications may overlap temperature ranges. For example, certain direct uses can be supported with

temperatures as low as 70°F, and certain power generation technologies can operate on temperatures as low as 200°F. Thus, the delineations of low-, moderate-, and high-temperature resources are intended to serve only as general guidelines for discussion and planning purposes.

Governmental Responsibilities

There are a number of governmental entities which monitor and regulate various aspects of geothermal exploration and development. These include federal, state, and local agencies, which often have similar or parallel responsibilities. Table 1 summarizes the major categories of governmental jurisdiction according to development phase and land ownership.

Land ownership is one of two primary criteria that determines which level of government is responsible for regulating a specific aspect of geothermal development. The other primary criterion is the ownership of the subsurface mineral rights, which the courts have determined to include geothermal steam. Secondary criteria for determining responsibility are related to the development phase being considered.

On federal lands geothermal resources may be leased by private entities or local governments pursuant to the Geothermal Steam Act of 1970 (Public Law 91-581). Administration of the geothermal leasing program in Siskiyou County involves two

Table 1

GOVERNMENTAL RESPONSIBILITIES FOR GEOTHERMAL DEVELOPMENT IN CALIFORNIA

AGENCIES

Federal

BLM	Bureau of Land Management
USFS	Forest Service

State

SLC	State Land Commission
CEC	California Energy Commission
DOG	Division of Oil & Gas
RWQ	Regional Water Quality Control Board
RAP	Regional Air Pollution Control District

NOTES

1. Requires USFS concurrence on National Forests.
2. Requires responsible agency concurrence per CEQA.
3. Can be delegated to County.
4. Requires CEC concurrence.
5. Can be delegated to County.

DEVELOPMENT PHASE	FEDERAL LANDS		STATE LANDS		PRIVATE LANDS	
	Requirement	Lead Agency[1]	Requirement	Lead Agency[2]	Requirement	Lead Agency[2]
Passive Exploration	Special use permit	BLM	Prospecting permit	SLC	NA	NA
Advanced Exploration (<6 wells)	Lease Plan of operations Environ. assessment Emission permit	BLM BLM BLM RAP	Lease Environ. assessment Drilling permit Land-use permit Emission permit	SLC SLC DOG County RAP	Environ. assessment Drilling permit Land-use permit Emission permit	DOG[3] DOG County RAP
Baseline Data Collection	Plan of operations Environ. assessment	BLM BLM	NA	NA	NA	NA
Field Development (>6 wells)	Plan of operations Environ. assessment Emission permit	BLM BLM RAP	Environ. assessment Drilling permit Land-use permit Emission permit	County DOG County RAP	Environ. assessment Drilling permit Land-use permit Emission permit	County DOG County RAP
Injection/Disposal	Plan of operations Environ. assessment Emission permit Discharge permit	BLM BLM RAP RWQ	Emission permit Discharge permit	RAP RWQ	Emission permit Discharge permit	RAP RWQ
Resource Production	Plan of operations Environ. assessment	BLM BLM	NA	NA	NA	NA
Resource Utilization (<50 MW)	Plan of operations Environ. assessment Plant site license Utilization permit Emission permit Discharge permit	BLM BLM BLM BLM RAP RWQ	Environ. assessment Plant siting permit Emission permit Discharge permit	County County RAP RWQ	Environ. assessment Plant siting permit Emission permit Discharge permit	County County RAP RWQ
Resource Utilization (>50 MW)	Plan of operations Environ. assessment Plant site license Utilizatioin permit Emission permit Discharge permit	BLM BLM BLM[4] BLM RAP RWQ	Environ. assessment Plant siting permit Emission permit Discharge permit	CEC[5] CEC[5] RAP RWQ	Environ. assessment Plant siting permit Emission permit Discharge Permit	CEC[5] CEC[5] RAP RWQ

federal agencies: the Bureau of Land Management (BLM), and the Forest Service (USFS).

The BLM is the lead federal agency for all aspects of geothermal exploration and development. Where resources occur beneath National Forest lands the USFS must concur with BLM decisions. As indicated in Table 1, these agencies require an environmental assessment and plan of operations for each major phase of geothermal development.

Other federal agencies that may be involved in Siskiyou County include: the National Park Service, by virtue of the Lava Beds National Monument; the Fish & Wildlife Service, given resource potentials in natural areas; and the USGS, which performs certain geothermal research functions.

In addition to federal lands, there are also instances of lands now privately-owned but for which the federal government retains subsurface mineral rights, e.g. homesteaded lands. By federal court interpretation the right to explore and develop geothermal resources on these lands is subject to the same management and controls as on other federally-owned lands.

In California there are several state agencies that exercise authority over geothermal resources. These agencies and their principal responsibilities are as follows:

- The State Land Commission (SLC) acts as a landlord for all state-owned lands and is responsible for leasing tracts of state land for the exploration and development of geothermal resources. The SLC sets additional requirements concerning environmental protection, multiple use, and development.

- The Division of Oil and Gas (DOG) administers regulations for developing geothermal resources anywhere in the state. DOG is the lead agency on all exploratory drilling projects where the land or the mineral rights are not under federal jurisdiction.

- The California Energy Commission (CEC) has responsibility for the siting of all thermal power plants rated at 50 megawatts (MW) or greater. This responsibility extends onto federal lands because of an agreement in California whereby the CEC shares siting authority with applicable federal agencies.

Several other state agencies are involved in reviewing the environmental documents prepared by the lead agencies for geothermal projects. Under the California Environmental Quality Act (CEQA) they are considered responsible agencies because they have approval power over a particular part of a project. These agencies include Regional Water Quality Control Boards, the Department of Fish and Game, local Air Pollution Control Districts, and the Solid Waste Management Board. Depending upon

circumstances, these agencies may sometimes be designated the lead agency for a proposed project.

All of these agencies conduct environmental reviews before granting their approval. They are required by CEQA to certify the adequacy of the environmental document which describes the environmental impacts of each geothermal project. This is true whether they be a lead or responsible agency. To accomplish this goal each agency applies its own standards and requires specific information necessary to satisfy its own regulations and permit requirements.

At the local level on non-federal lands counties exercise the most control over geothermal development. This is accomplished primarily through drilling regulations, land-use measures, and air pollution control.

Counties may regulate the use of privately-owned land through conditional use permits for the different phases of geothermal development. Use permits may be issued for exploratory and development drilling, and during development grading and building permits may be issued for roads and construction related to geothermal facilities.

Counties are designated by CEQA to act as the lead agency in preparing environmental documentation for development of a full field of wells supplying a geothermal project (full field development is defined by statute as six or more wells supplying

a single project). Counties also have the authority for siting power plants rated at less than 50 MW. Further, if a county's Geothermal Element is approved by DOG and CEC it can assume lead agency status for exploratory drilling projects and the siting of power plants over 50 MW.

County planning departments, by virtue of statutory requirements, perform the majority of local geothermal regulatory and administrative work. The responsibilities of the planning departments, as well as other county agencies involved with geothermal development, depend upon both the surface and mineral ownership of the land on which the development occurs. For projects where the surface and mineral rights are the property of the federal government, county planning departments are generally not involved. However, federal law does require that the BLM and other federal agencies adhere to applicable county plans and regulations concerning geothermal development wherever possible.

The State Air Resources Board has delegated certain types of emission control rule-making and monitoring to local air pollution control districts. Thus, for each geothermal development phase, regardless of location, the county air pollution control districts establish emissions limitations which must be met by developers.

Geothermal Experiences in Other California Counties

Siskiyou County is one of approximately 20 California counties with significant geothermal resources, and one of 12 counties containing federally-designated Known Geothermal Resource Areas (KGRA). Of the 12 counties with inferred high-temperature resources, eight are presently experiencing significant interest in geothermal development.

These eight counties, including Siskiyou, are shown in Table 2 along with their development status, local regulatory posture, and geothermal fiscal status. This information is presented to give Siskiyou County a comparative idea of the treatment of geothermal energy in other counties of California.

Establishment of Siskiyou County Study Areas

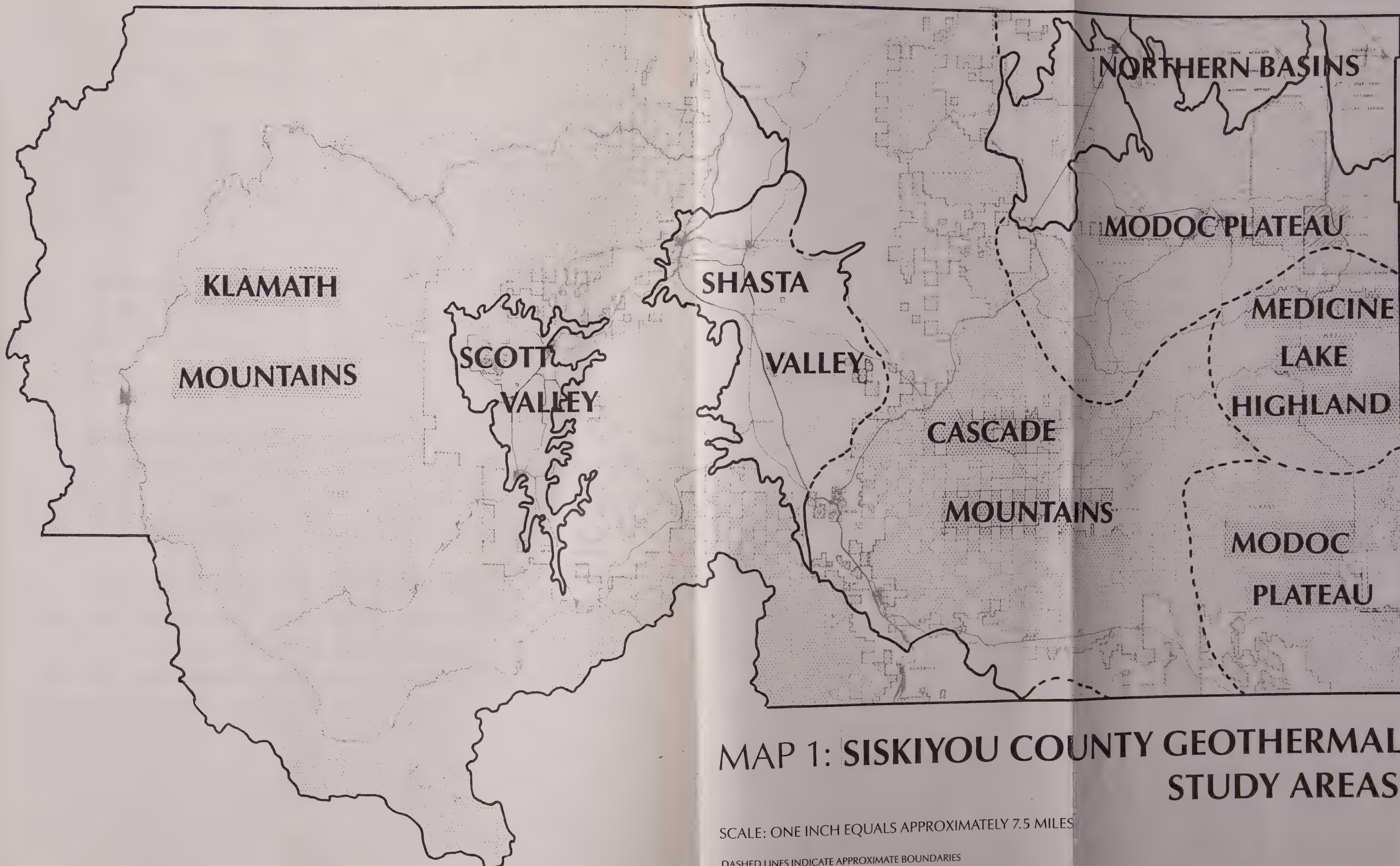
In order to facilitate the collection, interpretation, and presentation of geothermal information for Siskiyou County, the County has been divided into the following study areas, which are shown on Map 1:

- Klamath Mountains
- Cascades Mountains
- Scott Valley
- Shasta Valley
- Modoc Plateau
- Northern Modoc Basins (Tulelake, Lower Klamath Lake, Butte Valley)
- Medicine Lake Highland

Table 2
COMPARISON OF PRINCIPAL GEOTHERMAL COUNTIES IN CALIFORNIA
May, 1983

	Sonoma	Lake	Imperial	Inyo	Mono	Lassen	Modoc	Siskiyou
Estimated Geothermal Potential (MW)[1]	1,785	1,780	6,791	650	2,100	1,610	1,490	1,086
Geothermal Power (MW)								
On-line	883	135	30	-	-	-	-	-
Under construction	292	135	-	-	7	-	-	-
Planned	610	55	2,298	75	-	-	-	-
Geothermal Direct-Use On-line	Spas	Spas	Spas	Spas	Ag/Spas	DH/Ag	Ag	-
General Plan Geothermal Element (per OPR)	No	No	Yes	Pending	Yes	No	No	-
Geothermal Zoning Standards	No	Yes	Yes	Yes	Yes	No	Yes	-
Lead Agency: Exploration Well Permitting	No	No	Yes	Yes	Yes	No	No	-
Lead Agency: Field Development Well & <50 MW plant	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Plant Siting Authority (>50 MW)	No	No	No	No	Pending	No	No	-
Geothermal Revenues								
AB 1905 Lease Payments (1980-82 cumulative million $)	1.8	1.3	.27	.21	.35	-	.02	0.29
Tax Exempt Agency Agreements	Yes	Yes	-	No	No	No	No	-
Property Tax Revenues (FY 81-82 million $)	19	2.7	.64	-	-	-	-	-
Possessory Interest Taxes (FY 81-82 million $)	-[2]	-[2]	-[2]	-[3]	.01	-	-	-[3]

[1] Adapted from USGS Circular 790.
[2] Included in property taxes.
[3] To be initiated in FY 83-84.



MAP 1: SISKIYOU COUNTY GEOTHERMAL STUDY AREAS

SCALE: ONE INCH EQUALS APPROXIMATELY 7.5 MILES

DASHED LINES INDICATE APPROXIMATE BOUNDARIES

AFTER STRAND, 1964; AND GAY & AUNE, 1958

↑ N

Three of the subareas, the Klamath Mountains, Cascade Mountains, and Modoc Plateau, are major geologic and geomorphic provinces.

Shasta Valley is included as a separate area because of its unique geologic, geomorphic, and hydrogeologic conditions, and also because it includes several of the County's population centers.

Scott Valley has been separated from the Klamath Mountain province because of its unique hyrogeologic setting. The Valley contains a well developed and productive alluvial ground water aquifer.

The Medicine Lake Highland is an eastern extension of the Cascade province, but has been distinguished as a separate study area because it is the center of current high-temperature resource leasing and exploration activity.

The northern basins of the Modoc Plateau (Tulelake, Lower Klamath Lake, and Butte Valley) have also been classified as a separate study area because of their unique hydrogeologic setting, population concentrations, and geologic similarity to known low-temperature resource areas in southern Oregon.

Preparation of County Geothermal Bibliography

As a first step in documenting and evaluating the County's geothermal potential, a bibliography of all relevant scientific literature has been compiled. The bibliography, which is contained in Section 8 of the Geothermal Element, contains over 350 references on the geology of Siskiyou County and other geothermal-related topics.

This literature search has included all of the major published geologic maps for Siskiyou County. All publications listed between 1975 and the present, dealing with this subject were also included from the American Geological Institutes' Bibliography and Index of Geology. The remainder of the publications listed were obtained from interviews with geologists and other geoscientists with experience in the Siskiyou County area, or were drawn from the bibliographies of the primary references (those references most directly related to the Geothermal Element).

The bibliography is intended to serve as a reference tool providing comprehensive and up-to-date citations on geothermal investigations thus far in the County. New geothermal research publications should be added to the bibliography as they become available in order to maintain its usefulness.

Organizations Contacted

Numerous interviews and meetings have been conducted to identify additional resource information, sources of technical assistance for the County, and areas of regulatory jurisdiction. Major contacts have included:

- Dept. of Engineering and Geology
  College of the Siskiyous
  Weed, California

  Discussions have centered on the potential role of the College as a source of information on geologic activities throughout the County. The College has not been involved in any geothermal projects or studies to date, but has expressed an interest in relating existing programs on volcanology and seismology to geothermal resource potential, and in assisting the County in whatever way possible.

- Water Resources Department (WRD)
  Northern District
  Red Bluff, California

  Information has been obtained on current and past ground water investigations in Siskiyou County, and on WRD's role in ground water management.

- Water Resources Control Board (WRCB)
  Division of Technical Services
  Sacramento, CA

  Information has been obtained on the agency's role in water rights and waste disposal matters, and on the cooperative program between the WRCB and DOG for injection of waste geothermal fluids.

- Bureau of Reclamation
  Mid Pacific Region
  Sacramento, CA

  The Bureau has conducted ground water investigations in the Butte Valley Region, and information on the results of these studies have been obtained.

- Division of Oil and Gas (DOG)
  Sacramento, CA

  DOG is one of the lead agencies for geothermal resource development in California, but has had very little involvement with low-temperature resources. It has begun a computer file system for low-temperature production and injection information. The County may want to consider establishing a computer-based information system compatible with the Division's.

- California Division of Mines and Geology
Sacramento, CA

Information has been obtained on the Division's two phase program to assess the low- and moderate-temperature resources of California. Phase One of the project involved a site visit and preliminary assessment of only one site in Siskiyou County (Bogus Soda Springs). Phase Two should include more geochemical work in the County, but may not be completed if U.S. Department of Energy funding is not continued.

- Branch of Field Geochemistry and Petrology
Geologic Division
U.S. Geological Survey (USGS)
Menlo Park, CA

The Geologic Division of the USGS is responsible for ongoing geologic and geothermal research activity in the Glass Mountain KGRA. Information has been obtained on completed and proposed projects in the KGRA, and the Survey's overall resource evaluation program for the Cascades. Information has also been obtained on the background and objectives of the core hole that was drilled near Tulelake in May and June, 1983. It is hoped that this test hole will provide information on the volcanic history and geologic potential of the Tulelake area.

- U.S. Geological Survey
  Water Resources Division
  Sacramento, CA

  Information has also been obtained from the USGS on geologic and hydrologic conditions in the area of the Lava Beds National Monument.

Preliminary Characterization of Geothermal Information By Study Area

Following the designation of study areas, and completion of the literature search and initial organization contacts, the identified information was categorized on the basis of subject matter and location as shown in Table 3. The location categories describe the study areas cited earlier. The subject matter categories include six categories directly related to geothermal energy; a general geology category for those geologic subjects that are only indirectly related to geothermal resources; and a separate category for those publications dealing with mining.

Many of the publications listed in the bibliography deal with more than one subject or cover more than one study area. Each publication, however, is listed only once in Table 3. For example, USGS water supply papers cover geology, hydrology, and ground water, but they are only listed once under their primary category of ground water.

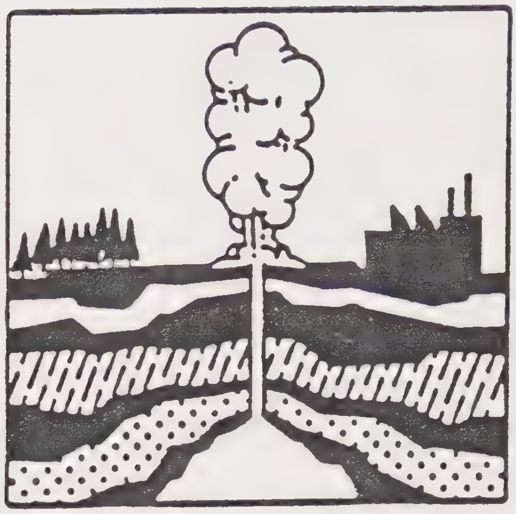
Table 3

AMOUNT OF GEOTHERMAL-RELATED INFORMATION, BY COUNTY SUBAREA
May, 1983

Subarea	General Geology	General Geothermal	Ground Water	Volcanism	Seismicity	Geophysics	Hydrology	Mining
Klamath Mountains	Moderate [140]	--	--	--	--	Limited [4]	Limited [1]	Limited [10]
Scott Valley	Moderate	--	Moderate [1]	--	--	--	Limited	--
Shasta Valley	Moderate [3]	--	Moderate [1]	--	--	--	Limited [1]	--
Cascades	Limited [8]	--[1]	--[3]	Moderate [17]	--[2]	Limited [3]	Limited [1]	--[3]
Medicine Lake Highlands	Moderate [8]	--	--	Moderate [13]	--	Limited [7]	--	--[1]
Modoc Plateau	Limited [4]	--[1]	Limited [3]	--[1]	--	Limited [3]	--[1]	--
Northern Modoc Basins	Moderate	--	Moderate [4]	--	--	--	Moderate [1]	--

Lack of an entry indicates no significant information. Superscript indicates preliminary number of bibliographic entries.

2.



LOW & MODERATE TEMPERATURE RESOURCE ASSESSMENT

Assessment Approach

Having reviewed the literature and contacted affected organizations, the next task has been countywide field work to assess the low- and moderate-temperature resource potentials of each study area. This field work has included a search of all available well records, site investigations in each study area, and an analysis of the combined information presently available for each area.

An assessment of geothermal resources in Siskiyou County must be based on an understanding of the County's geologic and hydrogeologic (ground water) conditions. A variety of geologic factors affect geothermal potentials. The natural heat required to raise ground water to above normal temperatures is derived from one of two sources, both of which are directly related to geologic conditions.

The first source is heat derived from volcanic or intrusive activity. In areas where molten rock from the earth's interior has risen into or broken through the crust during geologically recent times, the heat from that intrusive activity may support a geothermal system. Geologic factors such as crustal thickness, location in relation to crustal plate boundaries, and major structural trends determine where volcanic and intrusive activity has occurred or is likely to occur.

The second source of heat for geothermal systems is the natural heat flow of the earth's crust. Heat from the earth's interior is constantly being conducted outward through the crust toward the earth's surface. As a result, the temperature of crustal materials will normally increase with depth. Both the rate of temperature increase with depth (geothermal gradient) and the heat flow characteristics of a region are controlled by a variety of geologic factors including rock type, crustal thickness, and crustal structure. Rock type and crustal structure also play a major role in controlling how deep and at what rate ground water can circulate, and this too has a direct bearing on an area's geothermal potential.

The hydrogeologic or ground water conditions of an area are equally as important as the geologic conditions in controlling geothermal potential. Without the ground water resource to act as a means of capturing, holding, and transporting the earth's natural heat, the potential for deriving any significant economic benefits from that heat are lessened considerably.

All ground water is derived originally from precipitation. Precipitation, in the form of rainfall or snow melt enters the ground water system by percolating down through the soil, or by flowing into a stream or pond and then leaking into the permeable materials beneath that surface water body. The ground water then moves downward through pores, cracks, and other openings in the rock and soil materials until it reaches the zone of saturation (a depth below which all the openings are filled with ground

water). The surface of this saturated zone is referred to as the ground water table. The shape of the water table normally conforms, in a subdued manner, to surface topography, and in general, the distance to the water table is deep below upland areas and shallow in lowland or valley areas.

Water normally enters or recharges the ground water system in upland areas, and leaves or is discharged from the system in lowland areas. The path that ground water follows between the point of recharge and eventual discharge is called a ground water flow system, and such systems are normally referred to as being local, regional, or intermediate. These flow system designations are based on the relative depths and distances of ground water movement. A local flow system can be characterized as one where precipitation falling on a valley floor or canyon wall percolates down to the water table and then follows a relatively short and shallow path to the nearest seep, stream, or spring, where it is discharged as surface water. In a regional flow system ground water may reach depths of thousands of feet and cover distances of tens of miles before being discharged.

In addition to the flow systems described above, ground water can also occur as perched ground water. This situation develops when downward percolating ground water encounters an impermeable layer of rock or soil before reaching the water table. In these instances a perched saturated zone will build up above the restrictive layer. These perched ground water zones are commonly

the source of seeps or springs in upland areas, and in many instances are only seasonal features.

There are three general rules that apply to all ground water systems. They are: 1) that ground water is derived from precipitation; 2) that it will move from upland areas to lowland areas; and 3) that in all but a very few instances ground water movement is very slow, and will average between five feet a day and five feet a year.

If ground water in a zone or layer of saturated subsurface material can be withdrawn through wells, that zone or layer is called an aquifer. Good aquifers yield water easily to wells, and usually consist of materials that are porous and permeable, such as unconsolidated sands and gravels or indurated rocks that have numerous joints, fractures or other forms of secondary porosity. Poor aquifers, on the other hand, may be saturated, but will yield water very slowly to wells. These aquifers typically consist of fine textured alluvial deposits, or massive, well indurated bedrock.

A good aquifer must also have an adequate source of recharge. This is necessary in order to insure that water withdrawn through wells will be replaced by the natural system. If this does not occur, the water table will be lowered by continued pumping and the resource may eventually be depleted.

From the standpoint of geothermal energy, productive aquifers that are part of local or intermediate ground water flow systems are normally excellent candidates for the development of low-temperature geothermal resources. Ground water in these aquifers commonly has temperature and quality characteristics that are very desirable for heat pump applications. In addition, these aquifers are easily recharged and normally well suited to the establishment of quality and quantity monitoring programs. If properly managed, they can provide a long-term source of both ground water and low-temperature geothermal energy. However, because of their relatively shallow nature, aquifers that are part of local and intermediate ground water flow systems are rarely suitable for the development of moderate- or high-temperature geothermal resources. In fact, major low-temperature ground water flow systems may actually mask indications of higher temperature resources at depth (Mase and Others, 1982).

Aquifers that are part of a regional ground water flow system, especially if they are located in areas of recent volcanic activity or high heat flow, are most likely to produce moderate- and high-temperature geothermal resources. Ground water in these aquifers will characteristically circulate to great depths, and remain in the ground water flow system for long periods of time. The ground water is therefore more likely to be heated by the natural processes described earlier. Along with this increased potential for higher temperatures, however, is an increased potential for water quality and quantity problems. Ground water in these deeper aquifers is likely to contain more

dissolved solids and gases, and may not be recharged as readily as ground water in shallower systems.

Siskiyou County is geologically and hydrogeologically very diverse. As described earlier, four major geomorphic or geologic provinces have been designated as geothermal study areas (see Map 1): the rugged Klamath Mountains that cover the entire western half of the County; the Cascade Mountains that run north to south through the central portion of the County, including the Medicine Lake Highland in the east central portion of the County; Shasta Valley, which is situated in a geologic transition area between the Klamath and Cascade Mountains; and the western edge of the Modoc Plateau which extends from the Cascades to the County's eastern boundary. The Klamaths, Cascades, and Modoc Plateau are each geologically distinct and have been recognized as major and separate provinces by previous authors (Norris and Webb, 1976). The Shasta Valley was included as a separate study area primarily because of its distinct geomorphic setting and the fact that it is situated in a geologic transition area between the Cascades and the Klamath Mountains. It is also discussed separately because it is the site of several of the County's major population centers.

Three significant sub-provinces have also been designated as study areas. They are Scott Valley; Medicine Lake Highland; and the northern basins of the Modoc Plateau, which include Butte

Valley, Lower Klamath Lake Basin and the western portion of the Tulelake Basin.

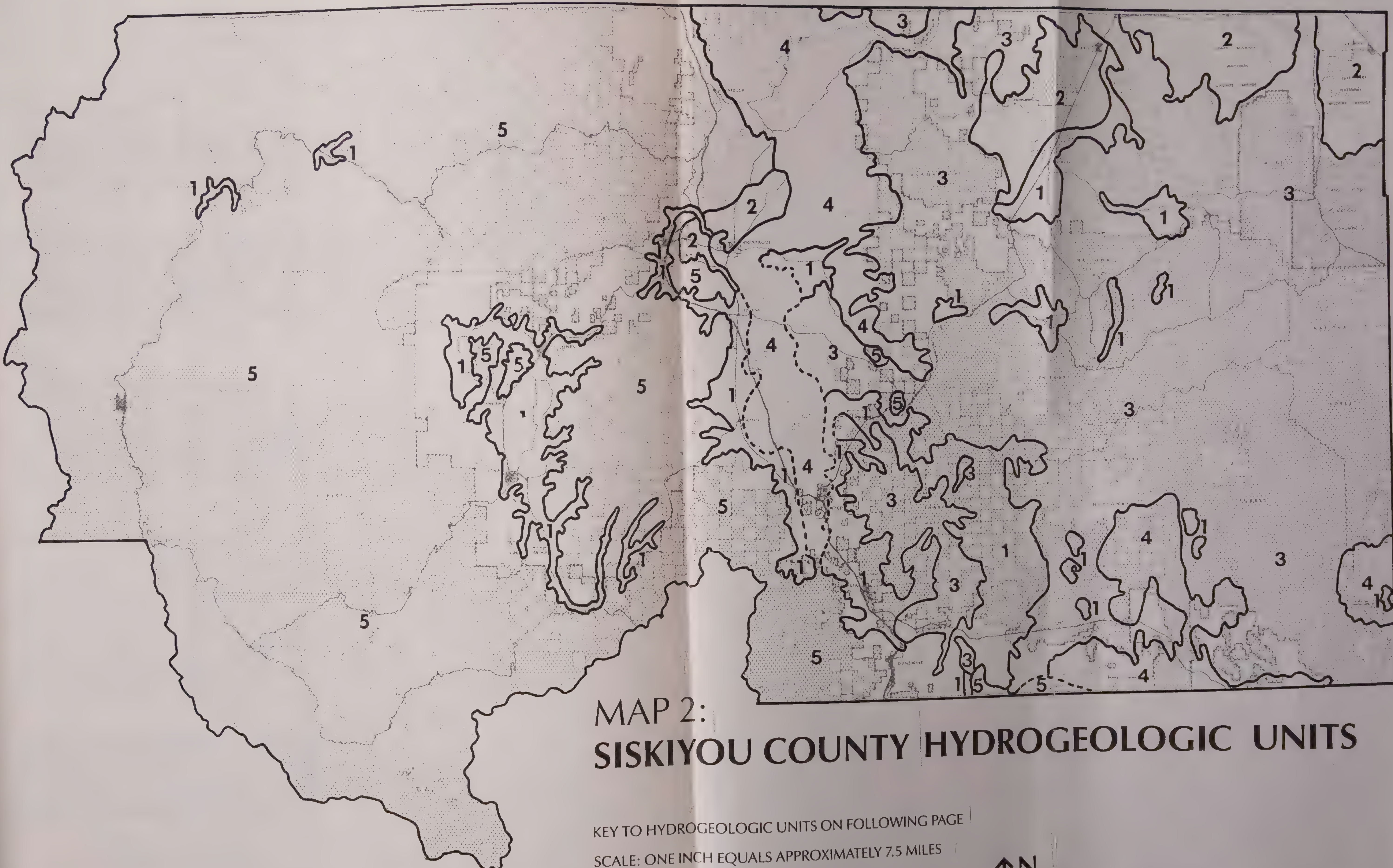
The bedrock geology of the Scott Valley area is similar to that of the rest of the Klamath province and the bedrock geology of the northern basins is characteristic of much of the Modoc Plateau. However, these areas have been designated as distinct sub-provinces because they are characterized by hydrogeologic conditions that are different from those common to their respective provinces. These two sub-provinces are major valley areas that contain highly productive and relatively shallow ground water aquifers.

The Medicine Lake Highland has been identified as a separate sub-province because of the predominance of recent volcanic landforms that occur throughout the Highland, and because of the high-temperature geothermal exploration that has occurred and is continuing in the area.

The geology and hydrogeology of each study area is described below, and the relationship of these factors to known and potential geothermal resources is discussed. Map 2 indicates the general boundaries of the hydrogeologic units in the study areas.

Klamath Mountains

For the most part, the Klamath province in Siskiyou County consists of several rugged mountain ranges that together make up a vast upland area with a general elevation of 6,000-7,000 feet.



MAP 2:
SISKIYOU COUNTY HYDROGEOLOGIC UNITS

KEY TO HYDROGEOLOGIC UNITS ON FOLLOWING PAGE

SCALE: ONE INCH EQUALS APPROXIMATELY 7.5 MILES

↑N

AFTER STRAND, 1964; AND GAY & AUNE, 1958

KEY TO MAP 2 HYDROGEOLOGIC UNITS

1. **Recent Alluvium**

   Unconsolidated clay, silt, sand, gravel and boulders, primarily valley fill and glaciofluvial deposits but also includes morainal debris. When saturated these deposits generally produce moderate to large quantities of good to excellent quality ground water. Excellent low-temperature geothermal potential, poor moderate-temperature potential.

2. **Quaternary Lake Deposits and Older Quaternary Alluvium**

   Unconsolidated to semi-consolidated clay, silt, and sand with occasional layers or lenses of gravel, diatomite, and volcanic ash which generally produce very small to large quantities of fair to good quality ground water. Fair to very good low-temperature geothermal potential, with locally fair to very good warm water potential from deep (>1000 ft.) wells in the Northern Basins sub-province.

3. **Pliocene – Holocene Volcanic Rocks**

   Basaltic and andesitic flows, domes, cones, and pyroclastic material that are part of or lithologically similar to the "high Cascade volcanics." Generally produce moderate to very large amounts of good to excellent quality ground water. Excellent low-temperature geothermal potential, and locally good moderate-temperature potential in the Northern Basins sub-province, and possibly throughout the Modoc Plateau and Medicine Lake Highland areas.

4. **Eocene – Miocene Volcanic Rocks**

   Primarily andesitic lavas and pyroclastic material but also includes basalt and dacite flows, rhyolite tuff and tuff breccias, and a few rhyolite domes. These rocks are part of or lithologically similar to the "western Cascade volcanics" with highly variable ground water quantity and quality characteristics. Fair to excellent low-temperature geothermal potential in the Shasta Valley and Cascade Mountains provinces, and fair to good moderate-temperature potential in the Cascade Mtns. province. These rocks have reportedly not been tapped by wells east of the Cascades, but may have good to excellent moderate-temperature potential in that area.

5. **Ordovician to Early Tertiary Metamorphic Sedimentary and Intrusive Rocks of the Klamath Mountains**

   Generally produce very low to moderate amounts of poor to good quality ground water. Low-temperature geothermal potential is quite limited due to quantity problems, and moderate-temperature potential is poor.

Some of the regional names given to these ranges include Scott Bar Mountains, Salmon Mountains, Trinity Mountains, Marble Mountains, and Siskiyou Mountains. The northern and central portions of the province are drained by the Scott and Klamath Rivers and their tributary streams, while most streams in the southern portion flow into the Salmon River system. Scott Valley, a major lowland area along the middle stretch of Scott River, and a few smaller valley features along the Scott and Klamath Rivers are the only significant lowland features in the province, and these will be discussed in a later section.

Seasons are sharply defined in the Klamath province, and climatic conditions and extremes can vary from severe in the mountainous areas to temperate in the lowland valleys. Precipitation in the upland areas is as much as 35-40 inches annually, and falls mostly in the form of winter snows (Mack, 1958), while precipitation in the Scott Valley area averages approximately 22 inches annually (California Department of Water Resources, 1964a).

There are no major population centers in the uplands of the province, and the economy for the limited number of people that do live in the area is based on forestry, mining, and tourism.

There are more than 140 references in the County geothermal bibliography (see Section 8) that deal with the geology of the Klamath Mountains. Despite this fact, a clear picture of the

area's geology and geologic history has yet to be developed (Norris and Webb, 1976). The vast size, rugged terrain, and limited accessibility of the area have limited work in the past, and it is only the area's importance as a key part in the plate tectonics puzzle that has spurred recent interest and activity in geologic mapping and research.

Basically, the bedrock geology of the province includes a subjacent or underlying sequence of marine sedimentary rocks that consist primarily of shale, sandstone, and conglomerate, but also include limestone, chert and volcanic rocks ranging from basaltic to rhyolitic in composition (Irwin, 1970). This series of rocks is more than 40,000 feet thick, and ranges in age from Late Ordovician or Silurian to Jurassic (Norris and Webb, 1976). During the Late Jurassic Nevadan Orogeney, these rocks were subjected to extensive isoclinal folding and thrust faulting, and granitic plutonic activity (Norris and Webb, 1976; Irwin, 1970). Ultramafic intrusive rocks that are of several ages, and that have been altered to serpentine are also common in this subjacent sequence (Norris and Webb, 1976).

The strongly unconformable overlying or superjacent series of rocks consists primarily of Cretaceous marine sedimentary deposits that were derived from the erosion and offshore deposition of subjacent series rocks that had been raised above sea level during the Late Jurassic tectonic activity (Irwin, 1970). Although a major portion of these sediments have been removed by post-Cretaceous erosional activity, deposits up to

5,000 feet thick do occur; but are primarily restricted to the margins of the province (Norris and Webb, 1976). Tertiary non-marine sediments reportedly are present in the province (Mack, 1960), but they are restricted in thickness and area of extent (Norris and Webb, 1976).

A period of normal and high angle reverse faulting of the Klamath province rocks occurred during the Mid to Late Cenozoic time. There is little evidence of any significant block faulting associated with this tectonic activity, with the possible exception of some Late Cenozoic features in the valleys on the eastern edge of the province (Norris and Webb, 1976).

There is very little information available on the ground water conditions in the upland areas of the Klamath Mountains, but in general the ground water production characteristics of the bedrock units would be classified as poor. The metamorphic, intrusive, and marine sedimentary rocks that make up the province typically have very poor porosity and permeability characteristics, and commonly will yield only a few gallons per minute of water to wells.

The steep slopes and poor soil permeability characteristics of the area encourage the runoff of rainfall and snow melt, and thereby reduce the potential for ground water recharge. The area's numerous cold water springs indicate that water that does infiltrate into the subsurface is likely to enter local perched

ground water flow systems and be discharged a relatively short distance down gradient. Under these conditions relatively little ground water enters deep, regional flow systems. Natural discharge from ground water systems occurs primarily as seeps, springs, and under flow in the major stream valleys.

The potential for developing low-temperature geothermal resources in the upland areas of the Klamath province is limited by the area's poor ground water production characteristics. Although there is no readily available information on the quality and temperature of ground water in the bedrock formations that underlie this area, it is anticipated that the water would be suitable for use in water source heat pumps. Adequate quantities of water however cannot always be obtained. Well production rates are commonly 10 gallons per minute (gpm) or less, but some wells that are completed in rocks with well developed joints or fractures reportedly produce 20-50 gpm. Because of the lithologic heterogeneity and the structural and stratigraphic complexity of the Klamath province, the prediction of ground water production potential in areas where there is little or no existing well information is difficult. However, any well capable of producing 10 to 30+ gpm could be used to provide water for a domestic or small commercial heat pump.

The potential for significant development of moderate-temperature geothermal resources in the Klamath province appears to be quite low. The area is characterized by low heat flow (Mase and others, 1982), and there are no reported areas of geologically

recent volcanic activity. This lack of positive heat source indicators along with the anticipated poor regional aquifer characteristics limits the potential for the development of moderate-temperature resources.

The geothermal and hydrogeologic characteristics of Sulphur Springs, the one known warm water resource occurrence in the province, have not been studied in detail. The springs are located along Elk Creek in Section 29 of T 15N, R 8E, HBM, and produce 10 to 20 gpm of 84°F water. Elk Creek Valley upstream of the spring site is a relatively linear northwest trending topographic feature, and the spring site is situated near the mapped contact between a granitic intrusive body and the surrounding metamorphic host rocks (Strand, 1964). It is probable that the Sulphur Springs water is derived from a deep regional ground water flow system, and that it migrates upward under artesian pressure along a fault, intrusive contact zone, or other structural feature. If this is in fact the case, it is possible that additional quantities of warm water could be obtained from wells near the spring site.

Hot springs and warm springs in scenic areas can often support recreational and/or health related businesses. However, no other reports of such springs in the Klamath province are contained in the literature, and references to claims by old timers of other hot springs were not confirmed by Forest Service personnel with numerous years of back woods experience in the area (Nitsche, 1983).

Although not identified as a separate study area, the Klamath River Valley (which also extends into the Cascades province) has several areas where erosional and depositional processes have combined to create relatively broad valley floors that are underlain by significant thicknesses (30 to 100 or more feet) of unconsolidated alluvium. The low-temperature geothermal potential of these isolated valleys appears noteworthy. Well log records indicate that, when saturated, the valley fill alluvial deposits are commonly capable of providing 20-60 gpm of water to standard domestic water wells. There is no readily available temperature or water quality information for these localized aquifers, but it is anticipated that water from them would be well suited for use in water source heat pumps.

Scott Valley

Scott Valley is located in the east central portion of the Klamath Mountains province (see Map 1). It is approximately 25 miles long and about 10 miles wide at its widest part, and includes the communities of Etna, Fort Jones, Greenview and Callahan.

In 1958 the USGS published a comprehensive report on the geology and ground water of Scott Valley (Mack, 1958). According to that report, the bedrock units in the Scott Valley area are hydrogeologically similar to those throughout the Klamath province. The 40,000 acre valley floor, however, is underlain

by unconsolidated stream channel, flood plain, and alluvial fan deposits. These sediments are reportedly more than 400 feet thick in the central portion of the valley (Mack, 1958), and range in size from clay to boulders. Unlike the bedrock units, these alluvial deposits have fair to excellent aquifer characteristics. The flood plain and stream channel deposits along the Scott River are capable of providing water to wells at rates of several hundred to more than 2,500 gpm, and although the fan deposits are generally less permeable than the stream channel and floodplain sediments, they too are capable of providing significant quantities of ground water to wells (Mack, 1958).

According to Mack (1958), the ground water in this relatively shallow alluvial system is recharged by the infiltration and downward percolation of incident precipitation, runoff from adjacent upland areas, and excessive irrigation water. Ground water flow in the valley basically follows surface topography and is toward the center of the valley from the valley margins, and then generally northward. Loss of ground water from the aquifer is by discharge to the Scott River, evapotranspiration, and withdrawal through wells.

In 1958 Mack estimated that natural discharge from the aquifer far exceeded artificial withdrawals, and that recharge to the system from incident precipitation alone was more than thirteen times the net amount of water lost through artificial withdrawal.

He also estimated the total amount of ground water in storage to be approximately 400,000 acre feet.

Like the rest of the Klamath Mountains province, Scott Valley appears to have little potential for the development of moderate-temperature geothermal resources. However, there is a significant potential for developing low-temperature resources from the valley fill alluvial aquifer.

The ground water in this aquifer is generally of excellent quality and is commonly between 50°F and 60°F (Mack, 1958). These facts, along with the abundant quantity and shallow nature of the resource make it well suited for use in water source heat pumps. Utilization of this resource could result in significant space heating and cooling cost reductions for Scott Valley residents and businesses.

Cascade Mountains

The Cascade Mountains province of Siskiyou County includes the north-south oriented volcanic upland area that runs through the center of the County, and the Medicine Lake Highland located near the County's east central margin (see Map 1).

The northern and eastern portions of the province are characterized by numerous 4,000 to 8,500 ft. heavily forested, volcanic peaks; and the 14,161 ft. high cone of Mt. Shasta dominates the landscape in the south. The Cascade Range receives

30-70 inches of precipitation annually, primarily in the form of heavy winter snowfall (Mack, 1960).

The majority of the province is undeveloped, and relatively uninhabited, the exceptions being several small communities located around the western and southern margins of Mt. Shasta. Timber and tourism-related industries are important to the study area's economy.

The geologic history of the Cascade Mountains province involves a relatively complex and not thoroughly understood sequence of volcanic activity combined with alternating periods of crustal downwarping and upheaval. The oldest rocks in the province are the meta-sedimentary and meta-volcanic rocks that make up the Klamath Mountains to the east. These pre-Late Cretaceous age rocks, and the Cretaceous and Tertiary marine and nonmarine sediments that unconformably overlie them outcrop on the western edge of the province. These rocks dip to the east northeast (Mack, 1960), and disappear beneath the northward trending volcanic uplands that make up the Cascade range. It is not clear how far to the east the Klamath group rocks extend. However, preliminary indications from regional seismic studies conducted by the U.S. Geological Survey are that these materials extend at least to and possibly beyond the north-south axis of the Cascade Range (Donnelly-Nolan, 1983).

The Eocene through Miocene volcanic rocks of the western Cascades unconformably overlie the Klamath type rocks. These volcanic

rocks consist primarily of andesitic lavas and pyroclastic material, but also include basalt and dacite flows, rhyolite tuff and tuff breccias, and a few rhyolite domes (Mack, 1960). Together, these volcanic deposits have a total thickness of more than 15,000 feet (Mack, 1960).

During the Pliocene and Pleistocene epochs tremendous volumes of basalt and basaltic andesite were erupted onto the eroded surface of the older andesites. Some of the flows covered more than 50 square miles, and the total volume erupted in the California Cascades was up to as much as two cubic miles (Norris and Webb, 1976). These outpourings of basalt created shield volcanoes such as Miller Mountain, Eagle Rock, the partly buried shield volcano under The Goosenest, Ball Mountain, Eagle Rock Mountain, and Secret Springs Mountain (Mack, 1960; Wood, 1960).

Volcanic activity continued through the Pleistocene and into the Holocene epoch, with andesitic and basaltic eruptions that formed the present peaks of The Goosenest, Willow Creek Mountain, Deer Mountain, and the Whaleback, as well as the main cone, parasitic cones, domes, flows and other volcanic features on and near Mount Shasta, and the variety of volcanic land forms in the Medicine Lake Highland area (Mack, 1960; Wood, 1960; Norris and Webb, 1976). The Plio-Pleistocene basalt dominated volcanics and the Pleistocene to Holocene andesitic and basaltic rocks are commonly grouped together and referred to as the high Cascade volcanics.

Pleistocene to Holocene glacially derived deposits cover much of the land surface on the flanks and around the base of Mt. Shasta. These materials consist primarily of poorly sorted morainal debris and well stratified glaciofluvial outwash deposits (Mack, 1960).

Structurally, the Cascade province in Siskiyou County is characterized by a regional east-northeast dip of 5-20^{o} for the western Cascade volcanics, and by north and northwest trending fault blocks along the eastern and western flanks of the range (Wood, 1960; Mack, 1960). The existence of a major north-south structure beneath the crest of Mt. Shasta has been proposed (Strand, 1964; Christianson, 1983), but has not yet been verified. In addition, evidence from the study of satellite imagery, outcrop patterns, and topographic characteristics indicates the possible existence of a northeast trending fault or series of faults running between Mt. Shasta and the Medicine Lake Highland (Donnelly-Nolan, 1983).

Very little is known about the hydrogeology of the Cascade Mountains province. It appears that the high Cascade volcanics are, for the most part, quite permeable; and that they serve as a very large area of ground water recharge (Mase and Others, 1982; Wood, 1960). Ground water in these rocks migrates down gradient along permeable zones such as joints, layers or lenses of pyroclastic ejecta, scoraceous interflow zones, and lava tubes. When they are saturated, the high Cascade volcanic rocks can be

excellent aquifers, and wells that tap them commonly produce several hundred to more than a thousand gpm.

Unfortunately, very little is known about the production capabilities of the deeper aquifers (western Cascade volcanics), or the overall regional flow system characteristics of the province. Mack (1960) reports that the western Cascade volcanics in Shasta Valley exhibit rapid changes in water bearing character both laterally and vertically, but that in some areas they can yield water at the rate of several hundred to more than 1,000 gpm to wells. Wood (1960) reports that, east of the Cascades, no wells are known to tap the unit. He speculates, however, that if wells were constructed production rates would be relatively low.

Ground water production rates in the glacial deposits are quite variable (Mack, 1960). However, well log records indicate that production rates of more than 1,000 gpm have been obtained from wells that tap permeable layers or lenses of sand and gravel.

The interpretation of regional flow system characteristics in the province is very difficult due to the lack of information on the degree of hydraulic connection between the high Cascade volcanics and the underlying volcanics of the western Cascades, and on the direction of ground water flow in the deeper aquifers. The effect that the major structural features have on ground water movement is also unknown.

Based on limited water quality data contained in the reports by Mack (1960) and Wood (1960), and on the well temperatures reported on well log records, it appears as if the abundant ground water resources in the Cascade province are well suited for use in water source heat pumps. Ground water quality is generally good to excellent, and reported ground water temperatures commonly range between 50 to 60°F in the northern portion of the province, and 45 to 55°F in the south.

Two moderate-temperature sites and one warm water site were identified in the Cascade province. The Bogus Soda Springs (located in Section 13, T 47N, R 5W, and producing 75°F water) were described by Mack (1960) as having quality characteristics possibly resulting from their occurrence in an area of known recent volcanic activity. However, Mack does not discuss the possible causes of the anomolous temperatures of these springs other than to state that they are probably associated with small displacement fractures. This conclusion tends to suggest that warm water resources at depth are migrating upward along structural conduits. Most wells in the northern section of the Cascade province have water temperatures that are in the 55-60°F range, and are too shallow (<500 feet) to provide information on deep aquifers. One documented exception to this norm is a 165-foot well drilled for Pacific Power and Light just below Iron Gate Dam (Section 9, T 47N, R 5W). This well has an artesian flow of approximately 60 gpm, and a temperature of 70°F.

With regard to moderate-temperature potentials, the 180°F+ springs near the summit of Mt. Shasta are encouraging in that they are indicative of a heat source at depth. However, all deep wells drilled close to the mountain have reportedly encountered only cold water. This would suggest that the summit hot springs are most likely the result of localized heating of ground water by fumarole activity, and that any geothermal reservoir that does exist is at an undetermined, but most likely great, depth beneath the mountain. The high-temperature fumarole at Medicine Lake is also encouraging, and is discussed in a section below.

The only other moderate-temperature resource site in the Cascades is the Klamath Hot Springs. These springs are reported by Higgins (1980a) as having temperatures of 156°F and a combined discharge rate of 95 gpm. The springs are located at the junction of what appears to be a major topographic lineation that trends northwesterly along Shovel Creek and the deeply incised canyon of the Klamath River. This combination of a possible structural conduit and a low topographic position are the primary factors controlling the location of the hot springs. Again, however, there is no information available on the depth to or temperature of water in the source aquifer.

With the exception of the summit springs on Mt. Shasta, and a fumarole at Glass Mountain, the Klamath Hot Springs are the highest temperature geothermal resource identified in the

County. Water from the springs was reportedly used in a swimming pool and bath house near the former community of Beswick. Presently the land surrounding the springs is owned by Pacific Power & Light Company.

The occurrence of warm water resources over a large portion of the Cascade province in northern Siskiyou County, and the relatively high temperature of Klamath Hot Springs are encouraging indicators that deep aquifers with moderate to high-temperature geothermal resources may exist beneath portions of the area. If, as is suspected, rocks of the Klamath group extend beneath the Cascades it is unlikely that the heat source for these thermal waters would be from high regional heat flow. It is more likely that heating occurs as a result of localized hot spots associated with geologically recent structural, intrusive or volcanic features; and that thermal waters occur adjacent to, above, and down gradient of these sites.

One of the major problems that must be dealt with in exploring for geothermal resources in the Cascades province is the effect of cold ground water flow systems on conventional exploration techniques. Mase and others (1982) reported that limited bore hole test data from the Cascade province in Siskiyou County was generally indicative of low heat flow and that it was typical of data associated with areas of major ground water recharge. They stated that this recharge process was capable of masking true heat flow characteristics to a depth of 300 meters, and that the effectiveness of conventional heat flow monitoring techniques

under such conditions is quite limited. The determination of the extent and character of moderate- and high-temperature geothermal resources beneath the Cascades in Siskiyou County will require the generation of additional geophysical, geochemical, and deep drill hole information.

Medicine Lake Highland

The Medicine Lake Highland is located to the east of the axis of the Cascade range (see Map 1), but is considered as a Cascade sub-province because of its volcanic history, and the fact that it has been a site of volcanic activity as recently as the early part of this century (Kilbourne and Anderson, 1981).

The Highland is a 0.6 mile thick, 16 mile diameter shield volcano comprised primarily of andesitic and basaltic flows, with a 5 mile by 3.75 mile caldera, 300 to 650 feet deep at its summit (Heiken, 1981). Recent volcanic activity has occurred on the flanks of the shield and within the caldera, and has included basaltic volcanism and the eruption of pyroclastics and lavas of intermediate to rhyolitic composition (Heiken, 1981).

USGS field work in the area indicates that almost all of the exposed volcanic material on the mountain is younger than 120,000 years, and possibly younger than 60-70,000 years (Donnelly-Nolan, 1983). This information, along with the evidence of very recent activity, suggests the presence of a significant heat source beneath the Highland.

Very little is known about the hydrogeologic conditions in the Highland area. The permeable nature of the young volcanics, the lack of surface water features on and around the Highland, and the low heat flow reported by Mase and others (1982) suggests the presence of a well developed, cold ground water flow system. No information is generally available however on the nature of the area's deep ground water resources. The Highland is built upon a plateau surface of Tertiary volcanics cut by numerous north to northwest trending normal faults (Heiken, 1981), and it is probable that productive aquifers exist at depth beneath the plateau surface (see discussion of Modoc Plateau province).

The combination of a volcanic heat source and a potentially productive deep aquifer makes the Highland a potential site for high-temperature geothermal resource development. Private exploration companies have been conducting test drilling for high-temperature resources on the Highland since 1982; and, although the information obtained is proprietary, indications are that the preliminary results are favorable. The strongest indicators of positive results are the expansion of the KGRA and the continued success of lease sales; and the reported plans for exploration companies to conduct deep drilling programs in the 1984 field season (Donnelly-Nolan, 1983). When the results of this drilling become available they will provide valuable information on the geothermal potential of the Highland area, and could provide geologic and hydrogeologic information that

will be useful in developing a better understanding of the geothermal potential of the entire east half of the County (also see related discussion in Section 4 of the Geothermal Element).

Shasta Valley

The Shasta Valley is a geologically interesting lowland situated between the Klamath Mountains on the west, and the Cascades on the east (see Map 1). It has an area of approximately 250 square miles, and is the site of the County's major population centers and main transportation corridor. The climate is of the Mediterranean type, with a mean average temperature of approximately 52°F and annual average precipitation of from 12-20 inches in various parts of the valley. Summer temperatures commonly rise above 100°F, while winter temperatures at times drop to zero °F.

Mack (1960) prepared a comprehensive report on the geology and ground water of Shasta Valley, and the following information has been derived primarily from that report. The oldest rocks in the area are the steeply dipping metamorphic and intrusive rocks of the Klamath Mountains basement complex that outcrop along the western margin of the valley. These rocks are unconformably overlain by eastward dipping (5-20°) Cretaceous marine and Early Tertiary non-marine sediments that outcrop only in the northwestern and northern sections of the Valley, and along an upthrown fault block near the east central valley margin. Next in the stratigraphic sequence are the andesitic western Cascade

volcanics. These rocks outcrop along a broad north-south band that extends through the center of the Valley. They have been eroded into hillocks that range in height from a few feet to several hundred feet, and, that from a distance, have the appearance of dozens of small volcanic cones. The southeastern portion of the Valley is dominated by the Holocene Pluto's Cave basalt flow that covers approximately 50 square miles. This flow originated on the northeast flank of Mt. Shasta and followed an established surface water drainage down onto the Valley floor. The flow is part of the high Cascade volcanics, and is the uppermost bedrock unit in the stratigraphic section of Shasta Valley.

Alluvial deposits cover the lowland surfaces of the Valley floor. Older Quaternary alluvium, usually less than 100 feet thick and consisting of boulders, gravel, sand, and clay, overlies the Cretaceous and Early Tertiary sediments in the northern portion of the Valley. Younger alluvium, consisting of unconsolidated sand, gravel, silt, and clay underlies the western portion and northeast corner of the Valley, as well as the lowlands between the eroded volcanic hills. Maximum thickness of the younger alluvium was reported by Mack (1960) to be 140 feet.

An area of about 35 square miles in the southeastern portion of the Valley is covered by morainal and fluvioglacial deposits derived from glacial activity on the northern flanks of Mt. Shasta.

The main structural features in Shasta Valley are the gentle (5^{o}-20^{o}) east northeasterly dip of the western Cascade volcanics and the underlying Late Cretaceous and Early Tertiary sedimentary rocks, and two narrow northwest trending fault blocks (Mack, 1960). The smaller of the two fault blocks is located just north of Snowdon, and vertical displacement along its eastern fault was reportedly between 200 and 400 feet (Mack, 1960). The second and larger fault block is located along the eastern margin of the Valley near Yellow Butte, and displacement along its eastern and western faults is reported to be approximately 1,000 and 2,000 feet respectively (Mack, 1960). Mack (1960) also reports apparent movement on the eastern Yellow Butte fault within the last few thousand years.

Ground water is an important, and relatively abundant resource in Shasta Valley. Domestic, commercial, industrial, and municipal wells draw water from all of the geologic units described above. However, there is a wide range of aquifer characteristics and production capabilities from unit to unit, and even within individual units.

The Pluto's Cave basalt is the most prolific aquifer in Shasta Valley, and irrigation wells tapping this flow have an average production rate of 1,300 gpm (Mack, 1960). Ground water production in the younger alluvium, morainal and glaciofluvial deposits and older volcanics vary considerably from site to site. Each of these units, however, is generally capable of providing adequate water supplies for domestic or irrigation purposes, and

production rates of several hundred gpm are common. The older alluvium in the northern part of the Valley, the Cretaceous and Early Tertiary sedimentary rocks, and the Klamath type metamorphic and intrusive rocks are generally less productive aquifers. Well production rates in these materials vary considerably but are normally satisfactory for domestic purposes; rates of more than 50 gpm are uncommon.

Surface runoff and ground water underflow from adjacent upland areas are the primary sources of recharge to the Shasta Valley aquifers. Additional recharge is derived from the infiltration of excess irrigation water, and, during wetter than average years, incident precipitation.

Ground water movement in the Valley's local and intermediate flow systems is towards the Shasta River from the adjacent upland areas, and then generally north northwesterly toward the Valley's surface water outlets. There is no information available on deep aquifers (>1,000 feet) or regional flow system characteristics.

The role that the normal faults near the eastern and northern margin of the Valley play in controlling ground water movement is not certain. Mack (1960) indicates that spring discharge points are common along the eastern Yellow Butte fault, and that artesian wells occur on the fault's upslope or eastern side. This tends to indicate that the fault or the uplifted fault block does impede movement of ground water from portions of the upland Cascade province into the Shasta Valley aquifers.

Ground water is lost from the Shasta Valley primarily by discharge to surface streams and by evapotranspiration. A significant amount of water is also lost through artificial discharge by wells.

The abundant ground water resources in Shasta Valley can potentially be developed as a source of low-temperature geothermal energy. With the exception of a few localized areas, ground water quality is good to excellent (Mack, 1960), and well log records indicate that water temperatures are normally between 55 and 60°F.

Yreka, the County seat, is located in the northwest corner of Shasta Valley, and in an area for which there is very little ground water information. The few well logs that are available, however, indicate that significant quantities of ground water may be available in the alluvial deposits that underlie the City. This possibility is further supported by the fact that several City-owned wells, shafts, and infiltration galleries were at one time used to draw water from these deposits to meet municipal water supply needs (Manley, 1983). If ground water is available, it is possible that water source heat pumps could be retrofitted to existing buildings located in the city, or installed in new buildings that are constructed. If this type of project could be completed successfully it would serve as an excellent demonstration of the low-temperature geothermal potential of those

portions of the County where adequate ground water resources are available.

There are no known occurrences of moderate-temperature geothermal resources in Shasta Valley. It is clear that the shallow ground water systems have no potential for moderate-temperature resource production, and there are several factors that limit the possibility that significant resources will be found at depth. These include: 1) the fact that the western Cascade volcanics, the most potentially productive bedrock aquifer at depth, appear to be hydraulically connected to a major cold water flow system; 2) the probability that the rocks of the Klamath basement complex, with their low heat flow characteristics, underlie the entire Valley area; and 3) the possibility that the movement of deep water from beneath the Cascades toward Shasta Valley may be impeded by north-south faults.

Modoc Plateau

The western edge of the 4,000-5,000 foot Modoc Plateau forms the eastern margin of Siskiyou County (see Map 1). This geologic province is characterized by broad plateau surfaces that are broken by north and northwest trending fault controlled valleys or basins, and geologically recent volcanic land forms, including cinder cones, lava and glass flows, and fragmental deposits (Norris and Webb, 1976). The region has a semi-arid climate characterized by average annual precipitation amounts of from 10-12 inches, warm dry summers, and cool humid winters (Wood, 1960).

In the northeastern section of Siskiyou County the fault block basins of Butte Valley, lower Klamath Lake, and Tulelake are the dominant landforms, and several communities that depend on the local agricultural and timber-based economy are located within these lowland areas.

In the relatively inaccessible southeastern portion of the County the pattern of northwest trending normal faults continues. However, a geologically recent basalt flow is the dominant landform, and there are no significant population centers.

The boundary between the Cascade Mountains and the Modoc Plateau is shown as a dashed line on Map 1. This is because there is no clear topographic boundary between the two provinces, and because the rock types exposed at the surface in both areas are quite similar. The boundary that is shown on Map 1 was drawn primarily on the basis of the presence or absence of faulting as shown on the regional geologic maps prepared by Strand (1964) and Gay and Aune (1958). Those areas characterized by extensive faulting were included in the Modoc Plateau province.

The oldest rocks exposed in the western portion of the province are the western Cascade volcanics (Phillips, 1980). As described earlier this group of andesitic volcanic rocks have a reported thickness of 12,000-15,000 feet, and were derived from eruptive activity along the ancestral Cascade range during Late Eocene to Late Miocene time (Wood, 1960). Norris and Webb (1976) report

that the Cedarville Series, an Oligocene to Early Miocene series of andesitic fragmental deposits with subordinate flows are the oldest exposed rocks on the Plateau east of the Medicine Lake area. There is no discussion by Wood (1960), Norris and Webb (1976), Hotchkiss (1968), nor Phillips (1980) as to the nature of the rocks that underlie the western Cascade volcanics or Cedarville Series. However, Eureka Resource Associates (1983) indicates that the 4,000-foot thick marine Cretaceous section exposed at Yreka dips eastward, and is present at depth beneath the Modoc Plateau.

The western Cascade volcanics and the Cedarville Series are unconformably overlain by an extensive but undetermined thickness of predominantly basaltic volcanic rocks that are part of, or lithologically similar to, the high Cascade volcanics described earlier (Wood, 1960; Phillips, 1980; and Hotchkiss, 1968). These rocks range in age from Pliocene to Holocene and include basalt and basaltic andesite flows, basaltic scoria and ash, palagonite tuffs and tuff breccias. In the northern basins these younger volcanics are overlain by several hundred to more than 2,000 feet of Pleistocene to Holocene lake bed deposits. These sediments are primarily clay, silt, and sand, but also include gravel, diatomite, and volcanic ash (Wood, 1960; Hotchkiss, 1968).

The faulting that is so predominant on the plateau was initiated in Late Miocene times (Norris and Webb, 1976) and has continued up to the present (Phillips, 1980). Vertical displacements along

faults in the Butte Valley area range from a few feet to possibly more than several thousand feet (Phillips, 1980).

There is very little information available on the ground water conditions of the Modoc Plateau in southeastern Siskiyou County. It is anticipated that the various volcanic rocks that underlie this area are, when saturated, capable of yielding moderate to large quantities of water to wells. Because of the lack of well information for the area, however, it is not possible to accurately estimate ground water depths, flow gradients, or temperatures.

In general, the limited amount of ground water information which is presently available prohibits the determination of the low-temperature geothermal potential for the Modoc Plateau. Exceptions to this conclusion occur in the three northern basins which are discussed below.

There are no known occurrences of moderate-temperature resources in the Plateau province outside of the northern basins. However, the area is undeveloped and relatively inaccessible, and there is only a limited amount of information presently available on geologic and hydrogeologic conditions. The presence of numerous northwest trending faults (Strand, 1964), and the occurrence of a hot spring and warm wells at Little Hot Spring Valley just a few miles southeast of the southeast corner of the County (Higgins, 1980a), are positive indicators of geothermal potential in the area.

Northern Modoc Basins

The final study area is the northern basins of the Modoc Plateau (see Map 1). In general, the northern Modoc basins have abundant ground water resources. The high Cascade volcanics and similar rocks characteristically have variable production capabilities, but generally provide large to very large (100 to 2,000+ gpm) quantities of water to wells (Wood, 1960; Hotchkiss, 1968). The lake deposits normally produce low to moderate amounts (10 to 50 gpm) except in those areas where sand or gravel layers or lenses result in higher production rates.

No wells are known to tap the western Cascade or Cedarville Series volcanic rocks in the northern basins area (Phillips, 1980; Hotchkiss, 1968).

Ground water recharge to the aquifers beneath the upland areas that surround the basins is derived primarily from the infiltration of incident precipitation and snow melt (Wood, 1960); while the sedimentary and volcanic aquifers beneath the valley floors are recharged primarily by infiltration from surface waters (Wood, 1960) and inflow and underflow from adjacent and underlying aquifers (Phillips, 1980).

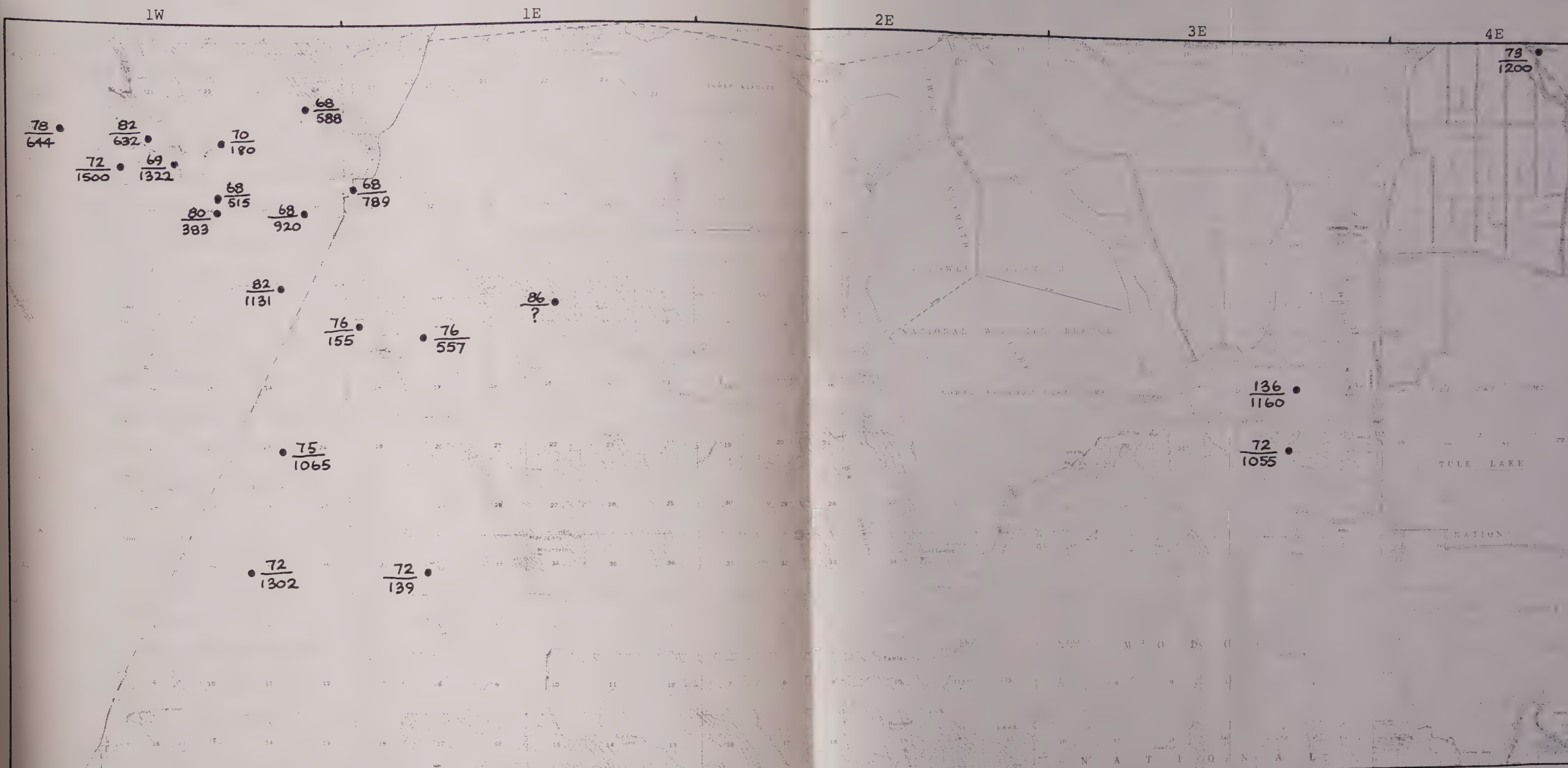
Ground water movement in Butte Valley is reported by Phillips (1980) as being generally toward the east, while Hotchkiss (1968) indicates that there is a southward gradient to ground water flow

in the Tulelake basin. The Phillips (1980) findings are interesting because they indicate that ground water in the northern basins may migrate across major faults. It is anticipated that the determination of the affect of major structural features on regional ground water flow systems will be an important factor in future interpretations of the geothermal potential of the Modoc Plateau province.

There is significant potential for the development of low-temperature geothermal resources in the northern Modoc basins. With the possible exception of portions of the lake bed deposits, all of the hydrogeologic units in the area are capable of providing adequate quantities of ground water to serve heat pumps. Ground water temperatures range between 50 and 60^{o}F, and the water quality is generally good to excellent (Wood, 1960; Phillips, 1980; Hotchkiss, 1968).

The northern basins study area has more known occurrences of warm water wells than any other area of Siskiyou County. As shown in Map 3, there are more than 20 wells distributed throughout the study area that reportedly have temperatures equal to or greater than 68^{o}F. The depths of these wells range from 139 to 2,676 feet, but depth does not appear to have any direct bearing on water temperature. Most of the wells, however, are located on or near faults, and they are in most instances situated nearer the upland margins of the basins rather than in the bottomland areas.

NOT SHOWN: TWO WELLS, T48N, R4E, S35, NE¼, SW¼;
BOTH REPORTEDLY 2,676 FT. DEEP PRODUCING 72°F WATER.



SCALE: ONE INCH EQUALS APPROXIMATELY 1.6 MILES

MAP 3: WARM WELLS IN THE NORTHERN BASINS

Temp (°F) / Depth (ft.)

N↑

Although a comprehensive study of the warm water wells in the northern Modoc basins area has not been conducted, the limited information that is available indicates that significant geothermal resources may be present at depth. Some of the positive factors are: 1) the widespread occurrence of warm wells throughout the sub-province; 2) the generally high yield capabilities of the wells; 3) the probability that the water temperatures reported for many of the wells may be lower than the potential maximum due to mixing of cold and hot water zones; and 4) the fact that the hottest reported well temperature in the County (136°F) is for a well near the eastern edge of the sub-province. These factors along with the positive regional characteristics of variably high heat flow (Mase and Others, 1982), numerous youthful faults (Wood, 1960, Hotchkiss, 1968, and Phillips, 1980), and recent volcanic activity (Donnelly-Nolan, 1983) support the possibility that additional moderate-temperature resources may be available.

It is not possible at this time to accurately characterize the ground water flow system or geothermal heat source that combine to produce the observed resource. It is likely, however, that the deep and reportedly untapped western Cascade volcanics and Cedarville Series rocks are the source aquifers for the geothermal fluids; and that the numerous north and northwest trending faults are the conduits along which the geothermal fluids migrate upward to reach the shallower aquifers.

It is also likely that both of the potential geothermal heat sources described earlier are contributing to the presence of geothermal fluids in the northern Modoc basins sub-province. Mase and Others (1982) describe the Modoc Plateau in general as having variably high (70-100 mWm^{-2}) regional heat flow characteristics, and there has been significant recent volcanic activity along the south central and south eastern boundaries of the northern Modoc basins sub-province.

Summary of Study Area Assessments

The foregoing assessment of the seven study areas is the first effort at documenting countywide low- and moderate-temperature resource potentials. This has been a relatively limited investigation, and as such it must be emphasized that initial findings need to be supplemented by further research. In general, however, it appears that the County has widespread potential for developing low-temperature resources suitable for water-source heat pumps; and in the northern Modoc basins it appears that notable potential exists for moderate-temperature resources. Each study area is briefly summarized below.

The Klamath Mountains province encompasses more than half the area of the County, and is perhaps its most geologically complex region. The bedrock materials that underlie the upland portions of the province have poor ground water production characteristics. This, along with the fact that the province is

a region of low crustal heat flow and no known recent volcanic activity, severely limits its geothermal potential.

Within the Klamath province, however, there are several lowland or valley areas that have excellent low-temperature geothermal potential. These valley areas, of which Scott Valley is the most significant, are underlain by shallow alluvial aquifers that contain ground water with temperature and quality characteristics that are well suited for water source heat pump applications.

The Cascade province, which includes the Cascade Range Mountains, and the Medicine Lake Highland, is an area characterized by geologically recent volcanic activity. Despite this fact there are very few hot springs or other surface expressions of geothermal resources. This is due in part to the fact that the province is also an area of significant ground water recharge. As a result cold ground water systems may tend to mask any signs of the moderate or high-temperature geothermal resources that are most likely present deep beneath the surface. In the northern section of the province, near the Klamath River canyon, there are indications that moderate-temperature resources may occur at shallower depths. However, there is very little hydrogeologic information available for this area.

Recently completed, ongoing, and planned research and exploration activity by public agencies and private companies in the Cascade

province should eventually provide more information on its geothermal potential.

In the Shasta Valley there are no known occurrences of moderate-temperature resources, and the area's ground water and geologic conditions are such that the potential for the existence of these resources, other than at great depth, is quite low. Like Scott Valley, however, Shasta Valley has abundant ground water resources that are well suited for use with water source heat pumps. The fact that Shasta Valley is also the site of many of the County's population centers and its primary transportation corridor increases the opportunity for deriving economic benefits from the development of the area's low-temperature resources.

The western edge of the Modoc Plateau forms the eastern margin of Siskiyou County. While there is very little known about the hydrogeologic and geothermal characteristics of the southern portion of the Modoc Plateau province in Siskiyou County, the northern basins area, in the northeast corner of the County, is the site of several occurrences of low- and moderate-temperature resources. Over twenty wells with temperatures greater than 68°F, including one well with a reliably reported temperature of 136°F, have been identified in this area. Although there has not been a comprehensive study of the geothermal characteristics of the region, there are several positive indications that

additional moderate-temperature resources may be available in the area's deeper aquifers.

It is apparent that many areas of Siskiyou County have abundant and readily developable low-temperature geothermal resources, and that moderate-temperature resources occur in the Cascade and Modoc Plateau provinces. The County's known low- and moderate-temperature resources are summarized in Table 4.

Further Resource Assessment Needs

Clearly, considerable resource assessment work remains to be accomplished in order to adequately define and characterize the County's geothermal resources. This work is most commonly divided between high-temperature efforts aimed at power generation, and low- or moderate-temperature work concerned with heat pump and direct-use applications.

Given the relatively small portion of the County that is believed to have high-temperature potential, and the extensive efforts currently underway by private industry, it appears that high-temperature assessment needs will be adequately addressed in the foreseeable future.

On the other hand, there remains an urgent need for further low- and moderate-temperature assessment in several areas of the County, such as the northern basins of the Modoc Plateau, and Shasta and Scott Valleys. The next phases of this work should

Table 4

KNOWN OCCURRENCES OF LOW & MODERATE-TEMPERATURE RESOURCES[1]

Source of Information	Type of Occurrence	Location	Temperature (°F)	Depth (ft)	Prod. Rate (gpm)
NORTHERN MODOC BASINS					
Phillips, 1980	Well	47N/1W-2J	82	1131	3300
		-23H	75	1065	-
		-35L	72	1302	3000
		48N/1W-28F	82	632	-
		-28J	69	1322	-
		-34B	68	515	-
		-34G	80	383	4000
DWR Logs	Well	47N/1E-7E	76	155	3000
		-8M	76	557	950
		-32N	72	139	100
		47N/3E-14G	136[2]	1160	1200
		-23F	72	1055	1000
		48N/1W-24P	68	588	1900
		-27G	70	180	-
		-29H	72	1500	-
		-30A	78	644	1200
		-36-	68	920	-
		48N/1E-31D	68	789	-
		48N/4E-16P	74	1200	2650
		-35L	72	2676	1200
Higgins, 1980[a]	Well	47N/1E-10B	86	-	-
CASCADES					
Driller	Well	47N/5W-9N	70	165	60
Higgins, 1980[a]	Spring	41N/3W-9Q	183	-	4
	Fumarole	43N/4E-3D	190	-	-
	Spring	47N/5W-13Q	75	-	20
	Spring	48N/3W-27L	156	-	95
KLAMATHS					
Higgins, 1980[a]	Spring	15N/8E-29Q	84	-	8

1 Not all locations and temperatures have been field checked. All locations Mt. Diablo Meridian except Klamaths, which is Humbolt Meridian.

2 The well log temperature for this well is 115°F. However, the driller reported that following well development work the water temperature increased to the 136° indicated (Van Meter, 1983).

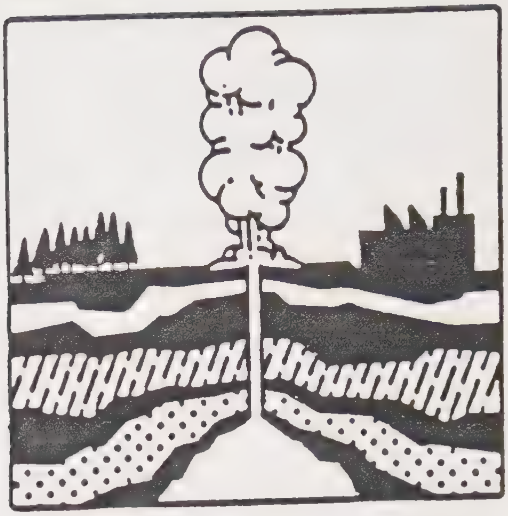
concentrate on two tasks: 1) the development and implementation of a countywide ground water data collection and management program; and 2) an expanded investigation of the geothermal potential of the northern basins of the Modoc Plateau.

Ground water is an extremely important natural resource in Siskiyou County, and yet there is no local program designed to monitor or manage this valuable resource. In addition, state agency ground water programs are quite limited in scope, and are often understaffed and underfunded. By establishing a ground water management program Siskiyou County would help to insure proper development of its low-temperature geothermal resources, and would be better able to assist the State in dealing with any future ground water problems.

Further, there may be significant economic benefit to be derived from moderate-temperature applications in the northern Modoc basins, where agriculture and industry could expand or diversify using geothermal energy. However, the extent and character of this potential is not yet well defined. Unfortunately state and federal energy programs can no longer be relied upon for identifying these types of resources, and therefore, the County should consider assuming a lead role in sponsoring such research.

Detailed recommendations for continuing resource assessment work are given in Section 6 of the Geothermal Element.

3.



LOW & MODERATE TEMPERATURE RESOURCE UTILIZATION

Overview

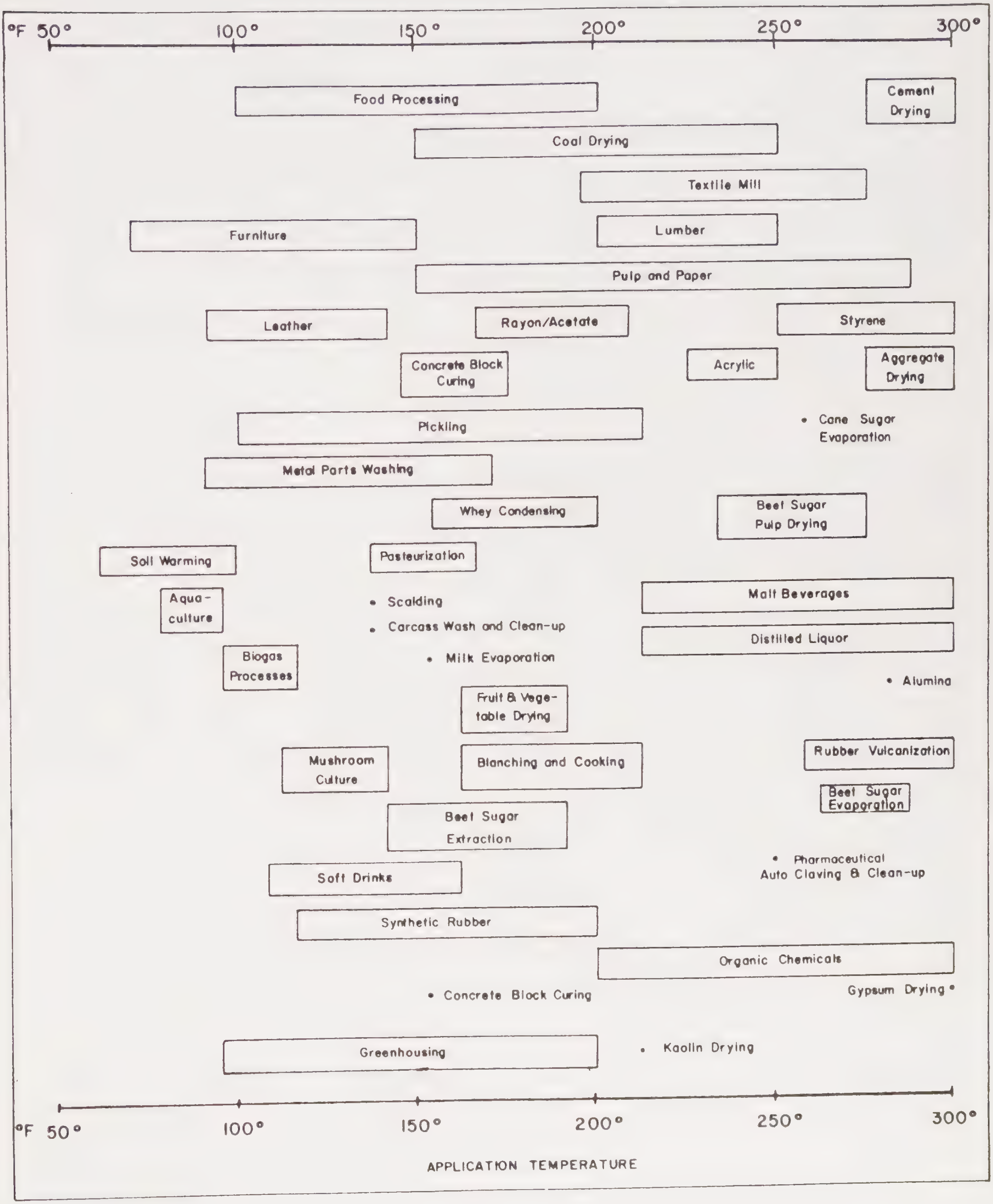
Low and moderate-temperature resources can successfully be utilized to supply thermal energy for a variety of uses. Figure 1 shows some of the agricultural, aquacultural, space heating, and industrial uses common in these temperature ranges. In addition, resources in the upper spectrum of this range ($200^{\circ}F+$) can be used to operate small-scale wellhead power generators.

Utilizing low- or moderate-temperature resources offers several advantages over the use of higher temperature electrical-grade resources, the chief of which is abundance. Resources with direct-use potential are believed to outnumber electrical-grade resources over ten to one. In addition, drilling costs and development lead times are often considerably reduced for lower temperature projects compared to those of higher temperature resources.

All of the applications shown in Figure 1, utilize known technology. Generally hot water is hot water, regardless of the source of heat. Utilizing the energy from low- and moderate-temperature resources requires straight-forward engineering and materials, and not major scientific advances. The technology, reliability, economics, and environmental acceptability of low- and moderate-temperature applications have been demonstrated throughout the world for decades.

Figure 1

SELECTED APPLICATIONS FOR LOW- & MODERATE-TEMPERATURE RESOURCES



The types of drilling, equipment, and uses that are likely to occur in Siskiyou County are described briefly below. These factors will constitute the most tangible impacts from low- and moderate-temperature resource utilization. While there are important environmental implications to low- and moderate-temperature resource use, environmental factors have traditionally been less significant in lower temperature projects. A detailed discussion of environmental and land-use issues for all temperature ranges is presented in Section 5 of the Geothermal Element.

Well Drilling

After performing preliminary resource assessment work in an area, the next phase of development is actual drilling to confirm and produce the resource. This takes the form of test or exploratory holes initially, followed by fully-completed production and injection wells. The latter refers to wells that are constructed for purposes of injecting spent geothermal fluids back to a producing aquifer. This practice provides an efficient and environmentally acceptable disposal method, while also contributing to the resource's long-term productivity. Drilling techniques for both production and injection wells are generally similar, and the discussion here is intended to be generic to most low- and moderate-temperature resource situations.

Low- and moderate-temperature drilling is similar to conventional water-well drilling. Typical drill rigs will either be cable-

tool or rotary. Cable-tool rigs are relatively inexpensive to operate, and allow casing to be driven directly behind the drill, thereby preventing hole cave-ins or lost circulation. However, cable tool rigs are not well suited for higher temperatures, nor depths below 1,500-2,000 feet. Rotary rigs are generally more expensive than their cable-tool counterparts, with the ability to drill as deep as 20,000 feet using large oil-type units. Rotary rigs also readily accept the blow-out preventors which are needed for the pressures encountered in high-temperature drilling.

In terms of impacts from these types of drilling the most common issues will be: proper access and location for the drill site; adequate containment of drilling fluids, and other supplies and equipment; hours of operation and the noise associated with drilling; the temporary visual presence of equipment; and the restoration of the site after drilling is complete.

In addition to the above-ground implications of drilling, there is also the issue of proper well construction and completion standards. If the beneficial use of geothermal resources is to be optimized it is important that wells be properly constructed to avoid problems. For low-temperature wells the California Department of Water Resources' water well standards apply (DWR Bulletin 74-81); and DOG's regulations for geothermal wells of all types (Public Resources Code Chapter 4, Division 3).

As low- and moderate-temperature utilization increases the County should consider its own local standards designed to maximize the resource's energy and economic values, and protect environmental qualities. These could be local standards developed in coordination with state agencies, aimed at simply ensuring that existing state regulations are properly followed. Or they could be new standards designed to address local site-specific concerns. For low- and moderate-temperature wells such items as casing, cementing, use of safety equipment, and proper logging would be likely areas of concern.

Once drilling has been completed the production or operating impacts from low- and moderate-temperature projects are usually limited. The relatively good quality of lower temperature resources results in few problems with adverse air emissions. Further, many direct-use systems are designed in a closed-loop manner such that fluids are never exposed to the atmosphere.

The most common production issue to be resolved in terms of environmental impact is resource disposal after heat extraction. As mentioned earlier, injection back to the producing aquifer is often recommended as a preferable disposal method. Other alternatives include consumption of the water for beneficial use, e.g. domestic or agricultural. Of the disposal alternatives, the injection method appears to be the most efficient of heat conservation. However, the location, temperature, and pressure of injection wells would also be issues that might properly be

monitored by a local regulatory program concerned with protecting resource capabilities.

A final issue of resource protection is the concept of reservoir engineering and monitoring. Once several wells begin to produce from a single resource area it becomes necessary to consider certain testing and monitoring procedures. These can be used to establish baseline temperatures, pressures, flow rates, and chemical qualities, that can be compared to operating values over time. From this data statistical models of the reservoir can be constructed to predict its performance, i.e. production of beneficial heat, under varying development scenarios, and management practices implemented accordingly.

Direct Applications

After drilling the next development phase is the above-ground use of resources. Low-temperature resources between 40-120^{o}F are often used in conjunction with water-source heat pumps, which are described in a following section. Allowing for a certain amount of overlap, temperatures from 70^{o}F up to 250^{o}F are considered to be in what is known as the direct-use range.

Direct utilization of geothermal energy means that the heat is used in its original state to warm buildings or to provide heat for industrial or agricultural processes. It is not converted to another form of energy such as electricity. There are advantages in using geothermal energy directly: it has a high energy

conversion efficiency; it uses resources which are widespread; and many readily available off-the-shelf items such as pumps, controls, and piping, can be used. Also, the time needed to develop lower temperatures is usually much shorter than that required for high-temperatures. All of these advantages add up to a favorable economic picture, especially when the rising costs of conventional fuels are considered.

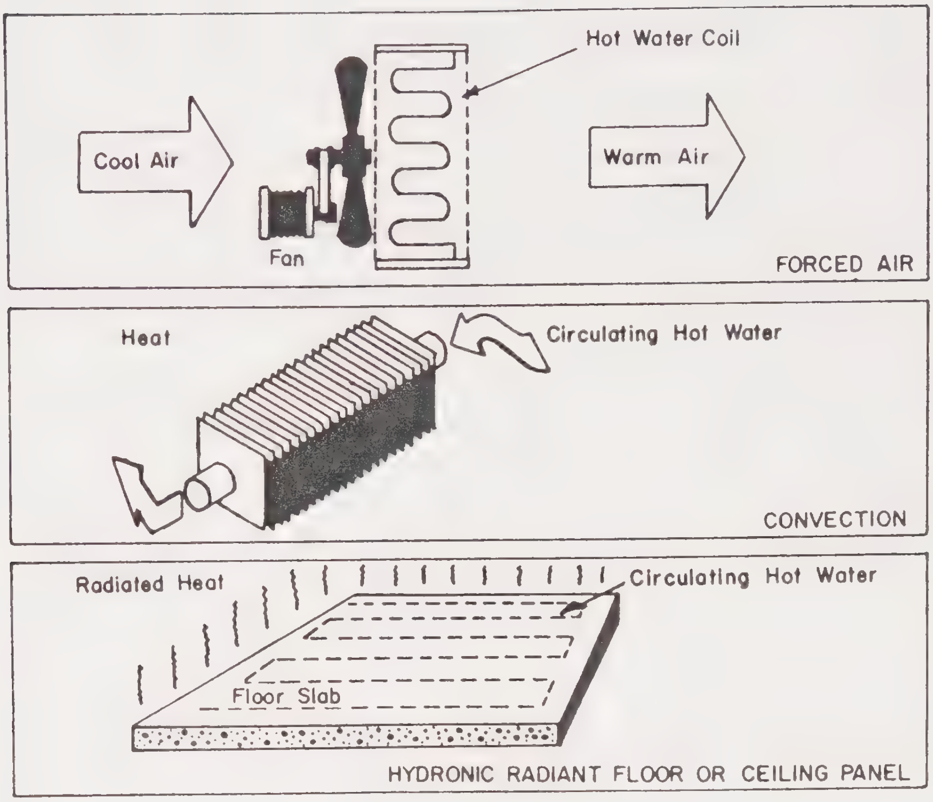
Direct-use is described here according to major applications in space conditioning, agriculture and aquaculture, and industrial processing; and the equipment commonly used.

Once drilling has confirmed a suitable resource, the fluids can be pumped through pipes to end-use equipment in residences, businesses, industries, or agricultural or aquacultural projects. The engineering concepts for all of these applications share the basic approach of circulating the geothermal fluids to a point where some form of heat conversion or transfer equipment extracts a certain amount of the geothermal heat, after which the cooler geothermal fluid is either circulated to a secondary use, or disposed of by injection or other beneficial means.

Generally the facilities and equipment needed to perform direct heat conversion are relatively simple and environmentally passive. In a home or business application geothermal fluids are simply circulated through a building's conventional heating equipment, i.e. fan-coil or radiant system. These types of systems are illustrated in Figure 2. In addition to heating,

Figure 2

DIRECT-USE SPACE HEATING SYSTEMS



resources above 180°F may be suitable for operating chilling equipment that can cool buildings.

In industrial applications direct-use resources often simply replace a fossil-fueled boiler, which is needed to supply heat or hot water for various processes, e.g. drying, scalding, washing. A food processing plant or lumber mill using direct-use resources would have no outwardly visible evidence of its geothermal use, except perhaps for a small pump house atop a wellhead. Internally the only major addition once again will be heat transfer equipment, generally what is known as a heat exchanger, which transfers heat from the geothermal fluids to a secondary fluid internal to the end-use facility, e.g. hot water used in cooking at a food processing plant.

In terms of agricultural and aquacultural applications, direct-use resources can be used for greenhouse heating, feedlot heating, soil warming, and fish farming. Once again end-use equipment is relatively conventional.

A common feature to all direct-use applications is the necessity to locate the end-use close to the resource because of temperature loss and expense in transporting the resource over distances. Generally direct-use temperatures cannot be cost-effectively piped more than a few miles to an end-use. Thus, it becomes necessary to allow end-uses to be located at or near confirmed resources. From a land-use planning perspective this

creates a need for flexibility in allowable uses in order to optimize the resource's capabilities.

Groundwater Heat Pumps

While the extent of known direct-use resources in the County is presently limited to the northern basins of the Modoc Plateau, the widespread occurrence of suitable ground water in many areas of the County suggests that low-temperature geothermal heat pump systems will represent a major share of the coming development of the County's geothermal resources.

At present the only geothermal applications in the County are ground water heat pump installations. Table 5 presents an inventory of several of these applications; it is expected that additional systems are also operating at other locations in the County, but were unable to be identified due to a lack of data. All of the systems in Table 5 are single applications, and all but one are residential.

Heat pumps are heat recovery systems which extract heat from a low-temperature source, use that heat to boost the temperature of a secondary working fluid such as freon, and then transfer the heat to a medium suitable for space and/or water heating. An air source heat pump utilizes outside ambient air as its energy source, while geothermal heat pumps extract energy from ground water. Ground water systems can generally operate on fluids ranging from 40-120°F.

Table 5

GEOTHERMAL HEAT PUMPS PRESENTLY IN USE

Location	User	Application	HP Type	HP Capacity (ton)	Water Temp. (^{o}F)
Yreka	Meeks	Residence	W-A	4	56
	Menne	Residence	W-A	4	56
	Smith	Residence	W-A	4	Pool
Big Springs	Louie	Residence	W-A	2 3 5	~55
	Truttman	Residence	W-A	3	~55
Etna	Reynolds	Residence	W-A	3	44-60
	Bartig	Residence	W-W	5	52
Fort Jones	Edgecombs	Commercial	W-A	3 3	44-55

[1] Water-to-air, W-A; water-to-water, W-W.

Groundwater heat pumps have two basic advantages over heat pumps that use air as the heat source. First, water has the highest specific heat of any common substance, four times greater than that of air. In other words, a given mass of water can store four times as much heat energy as an equal mass of air, and the water occupies a much smaller space. Second, ground water temperatures in northern California are fairly constant, with seasonal temperature changes from 10° to $20^{\circ}F$ in shallow ground water (less than 40 feet). There is generally no seasonal temperature variation in wells greater than 40 feet in depth. Air temperatures, however, are often too low for economical use in the winter when heat is needed, and too high in the summer when cooling is needed. When an air-to-air heat pump operates in these extreme temperatures its efficiency is reduced and more electricity is consumed.

Heat pumps may perform both heating and cooling functions using a ground water source. In the heating cycle ground water enters an evaporator, heating a refrigerant which then vaporizes due to its low boiling point and low pressure. The refrigerant gas is then compressed to a higher temperature and pressure, enters a condensor, and gives up heat to the building or process to which it is being applied. The refrigerant continues to circulate back through an expansion valve to decrease pressure and cool its temperature, allowing it to pick up more ground water heat on its next pass through the evaporator. In a cooling cycle the refrigerant flow is simply reversed by a reversing valve, and the

condensor and evaporator exchange roles, removing heat from building air and rejecting it to the ground water.

As with direct-use applications, ground water heat pump installations will not be unusually obtrusive. Conventional water wells are used for production and injection, where applicable; and the heat pump equipment normally occupies conventional mechanical space inside the facilities using the heating or cooling.

From an environmental standpoint the only major potential issue is the impact to ground water aquifers from limited heat extraction, that may be either non-consumptive or consumptive depending upon disposal methods. In this regard, impacts are generally dependent on two factors: operation of the equipment and method of disposal. The first area of concern is the possibility of contaminating an aquifer with freon from a leak that may develop in the water-to-refrigerant heat exchanger. Freon leakage should not be a significant concern because most heat pumps are designed with low refrigerant pressure cut-off switches to protect the compressor if a refrigerant leak should develop. The freon used in all residential systems and most commercial systems is also rated as non-toxic; and the oil used in the refrigeration system is not toxic, and is used in low quantities in comparison to aquifer volume. Further, freon is almost insoluble in water and would boil out of any water at atmospheric pressure.

The second area of concern, method of disposal, is more likely to result in environmental impacts. Methods of disposal of water from a ground water heat pump can be placed in one of two categories: consumptive or non-consumptive. The consumptive use of ground water in heat pumps involves the withdrawal of water and its subsequent disposal through beneficial use, e.g. domestic or agricultural, or surface run-off. The consumptive use of ground water in environmentally-sensitive areas may aggravate and even directly contribute to imbalance in a hydrologic system. Additional stress is imposed by ground water withdrawals which exceed storage or recharge capabilities, or both. The removal of ground water and method of disposal must therefore be evaluated on a site-specific basis. Further, the monitoring and careful management of ground water resources can avoid many of the problems associated with the consumptive use of ground water.

The non-consumptive use of ground water for the operation of heat pumps entails the discharge of water into an injection well after it has passed through the system. The hydrologic system would therefore maintain an equilibrium between inflow and outflow where the heat pump water is reinjected. However, the discharge water will be thermally altered; that is, the temperature of the water will be raised or lowered, depending on the mode of operation of the heat pump. The effect of this thermal alteration on the aquifer's hydrologic properties is the primary environmental concern associated with non-consumptive use. Several studies have examined cyclic heat extraction or

heat transfer through aquifer systems. Andrews (1978) simulated the impact of heat pump use for residential heating and cooling ground water temperature by means of a mathematical model. Ten years of simulated operation of a dual well system in a subsurface aquifer produced a change in water temperature of less than 1.8°F at a distance greater than 132 feet from the wells. This evidence indicates the injection of spent heat pump water should not adversely affect ground water temperatures if the use is properly managed.

As a general rule, the higher the temperature of geothermal resources, the more complex the regulatory requirements. Thus, ground water heat pump utilization requires a minimum of institutional obligations. Wells necessary for ground water heat pump systems are actually no different than standard water wells being developed for domestic use. Only a Water Well Driller's Report is needed for the supply well. This is usually completed by the drilling contractor and must be sent to the Department of Water Resources district office (Red Bluff for Siskiyou County). The heat pump equipment itself only requires installation according to the building code. The disposal system is perhaps the most institutionally sensitive. Disposal by injection requires compliance with the Federal Safe Water Drinking Act, administered regionally by the State Water Resources Control Board.

Given the County's widespread low-temperature resource base, and the efficiency and economy of geothermal heat pumps, it is expected that this type of resource development will increase in the years ahead and continue to account for a major share of geothermal use in the County. As this use increases the County should carefully monitor effects on groundwater, and in consultation with appropriate state agencies, consider implementing monitoring and regulatory measures to assure resource conservation and protection.

Wellhead Power Generation

At the upper end of the moderate-temperature range lies the third and final type of use that Siskiyou County may see its resources applied to: power generation. Generally, power is generated most effectively from high-temperature resources above 300^{o}F, but in recent years technological advances have reduced minimum temperatures to the point where small power plants can feasibly be considered for moderate-temperature resources.

Small-scale generators can use geothermal resources with temperatures from 180-300^{o}F to generate electricity. These systems are called wellhead generators since the energy is usually supplied by a single geothermal well. The systems range in capacity from 100 kilowatts (kw) to 10 MW. Organic Rankine Cycle (ORC) systems in the 100 kw to 3.5 MW range are believed to comprise the majority of units presently on-line throughout the world.

Interest in small-scale geothermal power development has been increasing in recent years as designs have improved, along with increasingly favorable economic returns. Small-scale wellhead power projects generally have shorter lead times, fewer institutional requirements, and often relatively smaller environmental impacts. These advantages combine to suggest that in the future, as knowledge of the County's moderate to high-temperature resources is increased, this type of utilization may gain favor.

Three technologies, flashed steam, ORC, and total flow, can produce electricity from moderate-temperature, i.e., water-dominated, geothermal resources. The flashed steam cycle is commercially proven and usually associated with higher temperatures. ORC technology, known in the geothermal industry as binary cycle technology, can use moderate-temperature resources, possibly as low as 180°F. However, ORC technology has yet to be commercially demonstrated in facilities smaller than 10 MW. Total flow uses both heat and pressure to generate electricity; these designs are in various stages of development and are not expected to be commercially available for geothermal applications until the mid-1980's.

It is important to note that the commercial operating history of these technologies is limited, and many persons in the geothermal industry believe that several years of continuing research and

development work must occur before small-scale wellhead generation becomes a readily feasible use for moderate-temperature resources. Nonetheless, interest remains high and numerous plants are either on-line, under construction, or being designed, as shown by the list in Table 6. It should be noted that some of these plants utilize high rather than moderate-temperatures.

Extensive resource assessment work remains to be performed in Siskiyou County before small-scale power generation is possible. Presently, there are no known resources outside of the Medicine Lake Highland that are hot enough to operate a generator. Such resources might be confirmed in the Cascade or Modoc Plateau provinces at some point in the future, perhaps in the northern basins of the Modoc Plateau, but not before further exploration and testing has been accomplished. If and when this occurs the County should again closely monitor development activities to determine what, if any, regulatory responses may be necessary.

Further, the County may wish to evaluate the feasibility of initiating its own geothermal generation program under the auspices of the County Power Authority which is currently developing hydroelectric generation.

The Local Basis for Low- and Moderate-Temperature End-Uses

If Siskiyou County's low- and moderate-temperature resources are to be used, their development will hinge on the local economic

Table 6

SELECTED SMALL-SCALE GEOTHERMAL POWER PROJECTS

(December, 1983)

Capacity (MW)	Location	Participants
1.6	Roosevelt KGRA, UT	Biphase Energy Systems; Phillips Petroleum; Utah Power & Light
0.5	Dixie Valley, NV	Geothermal Power; Sunedco
10-12	East Mesa, CA	Magma Power
6-10	North Brawley, CA	Union; Southern Calif. Edison
5.0	Raft River, ID	Hydra-Co Enterprises
3.0	Puna Rift, HI	Hawaiian Electric Light
10.0	Niland, CA	Southern Calif. Edison
2.1	Lakeview, OR	Woods Associates
6.0	Casa Diablo, CA	Westwood Geothermal; Ben Holt Co.; Mono Power

base and energy market. On the one hand, the local economy determines what type and size of geothermal applications are present or possible in the County; and on the other hand, the availability and price of competing energy supplies determine whether the cost of a geothermal system can be competitive.

In recent years throughout the western United States communities with agricultural and forestry-based economies in northern climates have often found low- and moderate-temperature applications to be competitive with fuel oil, natural gas, or electricity. It is important to note that geothermal applications are highly site-specific in terms of development and operating costs, and therefore economic generalizations about feasibility are difficult to support. The discussion here is intended to suggest economic potentials and not necessarily site-specific feasibilities, which must be evaluated on a case-by-case basis when geothermal utilization is being considered.

The County contains 4,038,843 acres, two-thirds of which is USFS land predominately in the Klamath National Forest. Interstate Highway 5 and U.S. 97 run north and south through the County, while State Highways 89 and 96 travel east and west. The area is served by railroads, bus lines, and numerous truck lines; at the present there is no scheduled airline service to the County. Major sectors of the local economy include livestock, field and truck crops, recreation and tourism, and lumber. Government agencies constitute the largest number of jobs in the County

economy, but the largest dollar volume producers are lumber and recreation/tourism.

Tables 7 and 8 characterize income and employment in the County. As shown in Table 7, the industries cited above account for about two-thirds of the total County income. Table 8 describes the last decade's trends by specific employment category. Clearly, the 1979-83 period was one of the County's most turbulent economic times, when unemployment was among the state's highest; however, despite such a severe cyclical downturn, the last decade of employment data reveals several general trends. The category of manufacturing which includes forest products dropped 63% in the last decade. During that same time period, farm employment dropped while farm proprietors picked up, resulting in relatively little net employment change. Government employment rose, as did trade and services.

Therefore, a decreasing segment of the population is dependent upon traditional job sources, particularly manufacturing; and an increasing segment of the population is employed in government or one of the service industries.

Thus, for the forseeable future low- and moderate-temperature resources will see the most opportunities for application in space conditioning for office and service facilities; space heating for agriculture, animal husbandry, and perhaps aquaculture; and industrial process heating for lumber

Table 7

SISKIYOU COUNTY ECONOMIC BASE

Industry	Proprietors	Employees	Income of Proprietors And Employees ($)
Farming & Ranching	735	489	45,252,000
Durable Goods (Incl. Forest Products)	NA	1,779	41,083,000
Government Employment	-	3,923	55,157,000
Total Economic Base	735	6,191	141,492,000
Total County Economy	2,915	13,238	222,147,000
Base As % of Total Economy	25%	47%	64%

Source: California Departments of Finance and Employment Development

Table 8

SISKIYOU COUNTY WAGE & SALARY EMPLOYMENT
BY SECTOR, 1972-1982[1]

	1972	1982	% Change
Total all industries	10,850	12,300	13.3
Agriculture	800	1,150	43.7
Production	675	800	18.5
Services, forestry & fisheries	125	350	180.0
Total nonagriculture	10,050	11,150	10.9
Construction & mining	525	325	-38.0
Manufacturing	2,725	1,125	-58.7
Lumber and wood products	2,525	925	-63.4
Other manufacturing	200	200	NA
Transportation & public utilities	1,000	850	-15.0
Wholesale trade	300	475	58.3
Retail trade	1,525	2,100	37.7
Finance, insurance, and real estate	350	450	28.5
Services	1,125	2,050	82.2
Government[2]	2,500	3,775	51.0
Federal	650	1,000	53.8
State	350	450	28.5
Local & education[3]	1,500	2,325	82.5

1 Employment reported by place of work. Does not include the self-employed, volunteer or unpaid family workers, private household workers, and persons involved in labor-management trade disputes.

2 Includes all civilian employees of federal, state, and local governments, regardless of the activity in which the employee is engaged.

3 Local government includes employees of counties, cities, and special districts. Education includes employees of public schools at both the state and local levels.

Source: California Employment Development Department, 1983.

manufacturing or new industries requiring low or moderate-temperatures. Specific targets for such resource applications are discussed in the following section.

Before moving to specific Siskiyou County end-uses, the local energy market needs to be considered in terms of geothermal energy's competitiveness among other available fuels. A given geothermal application must return enough savings or revenue to offset the investment required for constructing and operating a geothermal system.

Table 9 indicates current prices for energy available in Yreka. These availabilities and prices vary to a certain extent throughout the County, but the Yreka data is considered representative of the general prices against which low- and moderate-temperature resources must compete. Unit costs are difficult to compare so units are standardized in dollars per British thermal units (Btu). Combustion efficiencies are important too, as fuel oil and gas furnaces are frequently somewhat inefficient, e.g. 60-70%. When units are standardized and efficiencies considered true comparison occurs: electricity and propane are similar in price while oil holds a temporary price advantage over them due to a current surplus of supplies. Wood is also used extensively as a local heating fuel but estimates of its use and costs are unreliable due to limited data on consumption.

Table 9

LOCAL ENERGY PRICES

(Yreka, January, 1984)

Type	Unit Cost ($)	Cost/MMBtu ($)
Fuel Oil	0.99/gal	11.00[1]
Propane	0.97/gal	16.31[2]
Electricity Average Residential	0.056/kwh	16.41[3]

1 Assumes bulk rate of No. 2 oil with 138,600 Btu/gal. at 65% efficiency.

2 Assumes 91,500 Btu/gal. at 65% efficiency.

3 Assumes 3,413 Btu/kwh at 100% efficiency; average shown is exclusive of demand charges.

It is worth noting that the most recent survey of geothermal direct-use prices in the western United States indicates an average price for geothermal direct heat of $3.80/MMBtu (Sifford, 1982), which is considerably below current competing fuel prices in Siskiyou County. However, it must be emphasized once again that geothermal costs are highly site-specific, according to factors such as resource depth, quality, and distance to end-use; therefore, the economics of each geothermal project must be evaluated on a case-by-case basis.

Potential End-Use Targets

In addition to converting existing businesses and public facilities to geothermal use, there is also considerable potential for new industry to utilize low- and moderate-temperature resources. Thus, geothermal energy becomes a tool for stabilizing and strengthening the existing local economy, while also helping to diversify it through the attraction of new businesses or facilities that can benefit from low cost renewable energy.

Siskiyou County has recently completed a target industry analysis which identified twelve types of industries that have favorable potential for establishment in the County. Table 10 lists these current local targets according to their priority for location in the County, and their suitability for geothermal use.

Table 10

CURRENT TARGET INDUSTRIES OF THE COUNTY
ECONOMIC DEVELOPMENT PROGRAM

Industry[1]	SIC Code	Potential Geothermal Applications: Heating/ Cooling	Water Heating	Process Heating
Miscellaneous plastic products	3079	x	x	x
Fabricated plate work	3443	x	x	
Special machinery	3559	x	x	
Pumps and pumping equipment	3561	x	x	x
Industrial controls	3622	x	x	
Electronic components	3679	x	x	x
Process control instruments	3823	x	x	
Electrical meters & test equipment	3825	x	x	x
Surgical & medical instruments	3841	x	x	
Surgical appliances & supplies	3842	x	x	
Costume jewelry	3961	x	x	
Lumber, plywood & millwork wholesale trade	5031	x	x	x

Source: Siskiyou County Private Industry Council

As can be seen in Table 10, the known availability of low- and moderate-temperature resources may be able to help the County in attracting several of the industrial targets, suggesting that geothermal energy can become a direct job creator for the County.

When the County's current economic base and prospects for growth and diversification are combined it is possible to formulate a prioritized list of the most favorable low- and moderate-temperature resource applications. This target list, as shown in Table 11, is intended to help organize the County's efforts to stimulate low- and moderate-temperature utilization. The types of target applications shown in Table 11 are purposely generalized because of the site-specific character of geothermal energy described earlier. The technological, economic, and environmental feasibility of site-specific end-uses remain to be evaluated on a case-by-case basis.

During preparation of the Geothermal Element several opportunities for low- and moderate-temperature applications were identified as having favorable prospects for either retrofitting or new construction in the near future. These are summarized below as examples of the types of geothermal uses that are likely to increase in the County:

- County Courthouse and new jail. This is a public facility complex that has received detailed evaluation for a geothermal heat pump system,

Table 11

RECOMMENDED END-USE TARGETS FOR SISKIYOU COUNTY
LOW AND MODERATE-TEMPERATURE RESOURCES

	Application		
Public Sector	Space Heating/ Cooling	Water Heating	Process Heating
Local government offices	x	x	
Schools	x	x	
Correction facilities	x	x	
Swimming pools		x	
Power generation			x
Private Sector			
Agriculture (confined growing)			
Horticultural products	x		
Beef and pork	x	x	
Poultry and eggs	x	x	
Solid vegetables	x		
Fresh milk & pasteurization	x	x	x
Food & Related Products			
Meat processing	x	x	x
Vegetable processing	x	x	x
Animal feed processing	x	x	x
Beverage manufacturing	x	x	x
Lumber & Wood Products			
Sawmills and planing mills		x	x
Furniture and wood products	x	x	x
Chemicals & Related Products			
Agricultural chemicals		x	x
Industrial chemicals		x	x
Synthetic plastics	x	x	x
Treated minerals		x	x
Power Generation			x

resulting in a conclusion that 56°F ground water could operate a heat pump system for heating and cooling with an economic payback of six years. Work on this project is continuing at this time.

- New Yreka hospital. The consideration of a new hospital in Yreka could also include a geothermal heat pump system capable of supplying heating and cooling, as well as the large amounts of hot water necessary for hospital operations. With advanced planning the hospital could be sited to optimize geothermal opportunities.

- Dorris High School. In the future if this facility is either completely rennovated or replaced by a new structure the known presence of 80°F fluids in the community suggests that serious consideration of a geothermal heat pump system for space heating and cooling, and hot water heating, is warranted.

These are only three examples among several cases where existing buildings that must replace heating and cooling equipment, or new construction must choose equipment to install, should consider low- and moderate-temperature resources.

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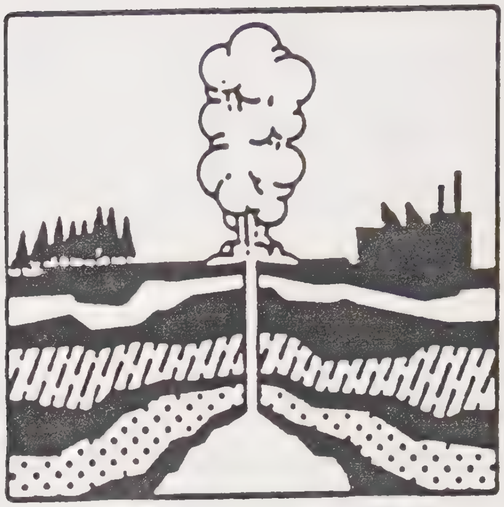
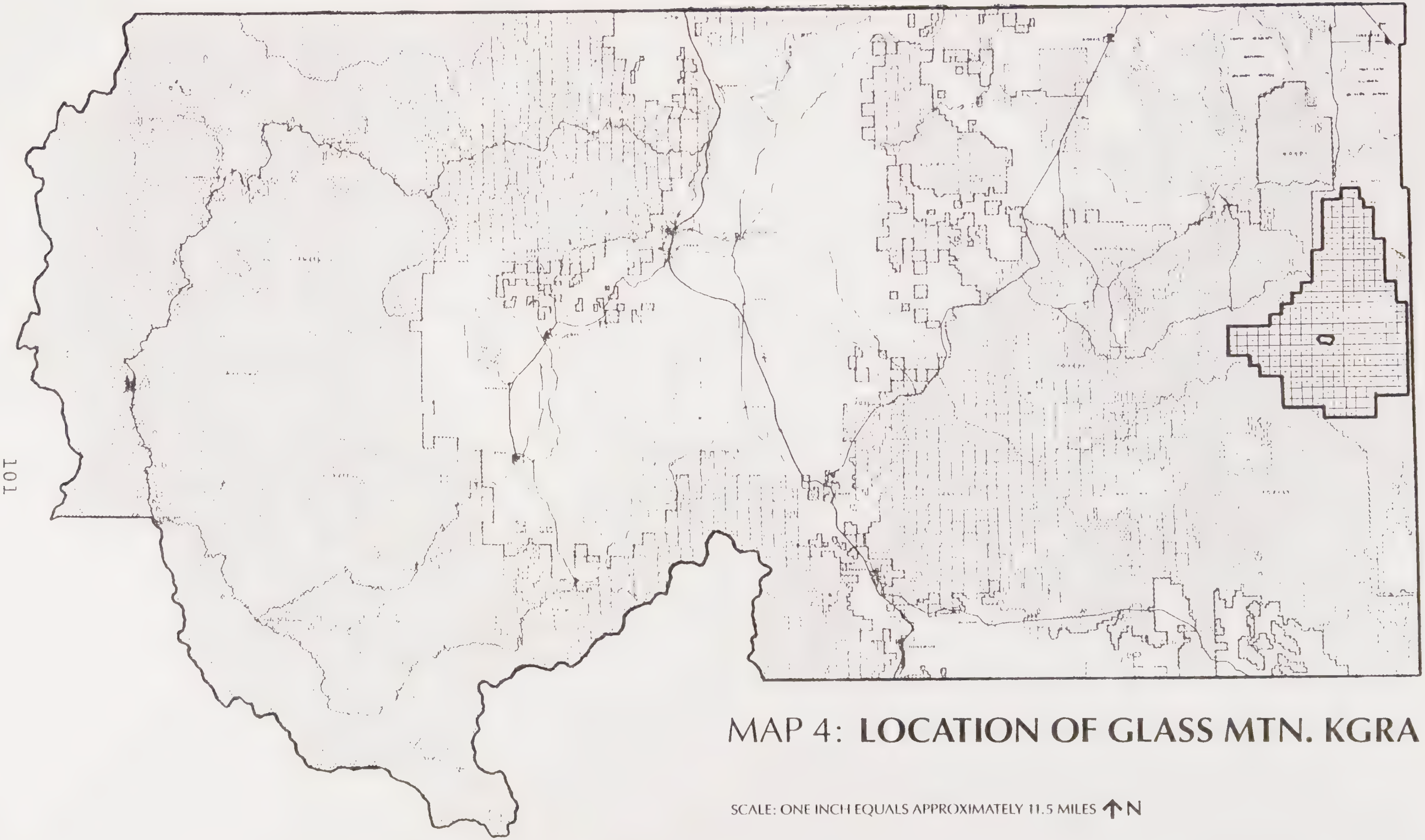


HIGH TEMPERATURE RESOURCES

Potential High-Temperature Resources

As indicated earlier, the County's geothermal resource base appears to be predominantly in the low- and moderate-temperature ranges. However, a major exception is the high-temperature potential believed to be located in the Medicine Lake Highland. Research and exploration thus far indicate that this area, along with perhaps others in the Modoc Plateau and Cascades, possess significant amounts of high-temperature resources suitable for generating electricity. However, it is important to emphasize that very little is known or certain about such resources thus far, and the discussion here is premised on the assumption that there will be continued success in developing a commercial-grade high-temperature resource.

The Glass Mountain area of the Medicine Lake Highland was determined to be potentially valuable for high-temperature resources in 1967, and a federal Known Geothermal Resource Area (KGRA) was established in 1971. The KGRA, shown in Map 4, is located in east central Siskiyou County, adjacent to the Modoc County line. The entire KGRA is within the Medicine Lake Highland, which, as described earlier, is a broad upland, located on the eastern boundary of the Cascade Mountain province, with elevations that range from 4,000 feet to 8,000 feet. A portion of Lava Beds National Monument is within the KGRA.



MAP 4: **LOCATION OF GLASS MTN. KGRA**

SCALE: ONE INCH EQUALS APPROXIMATELY 11.5 MILES ↑N

The Highland is an area of diverse volcanism with extrusive activity spanning the last two million years (Mertzman, 1981). The youngest flows may be less than 1,000 years old and eruptions at Glass Mountain may have occurred as recently as 1910 (Finch, 1928). The Highland is about 30 miles east-northeast of Mount Shasta and is the southern-most of a discontinuous belt of shield-like volcanoes which lie 15-40 miles east of the High Cascade strato-volcanoes. The original andesite shield volcano at Medicine Lake Highland appears to have been about 20 to 30 miles in diameter and 2,500 feet above its surroundings, but has since collapsed to form a caldera six miles long and four miles wide. Several rim volcanoes have buried the former caldera boundaries. Medicine Lake occupies the bottom of a depression formed between the ring cones. Glass Mountain is an obsidian dome and lava flow extruded through a pumice explosion cone and is on a fissure trending N30W. The pumice beds in the Glass Mountain locality appear to be 1,400-1,700 years old (Chesterman, 1955).

The rocks of the Cascade Range and the Modoc Plateau, of which Medicine Lake Highland is a part, are thought to overlie the Paleozoic and Mesozoic metamorphic, sedimentary, and plutonic rocks about which very little information is available. According to Hinds (1952) Cretaceous sediments underlie the eastward bulge of the Cascade Province. Tertiary andesite and basalt flows were extruded onto the eroded Cretaceous surface, and the Tertiary flows were in turn covered by Quarternary

volcanic materials from the Medicine Lake caldera. According to Anderson (1941), the distribution of rhyolitic rocks indicates that they are probably related to a volcanic center beneath the present Medicine Lake Highland.

The Bouguer Gravity anomaly maps of Chapman and Bishop (1968) defined a positive anomaly around Medicine Lake. Finn and Williams (1982) have gravity data which indicates a shallow intrusion under Medicine Lake volcano. Also, Stanley (1981) defined a regional magnetotelluric (MT) anomaly at the KGRA.

Seismic studies have defined an intrusive body under Medicine Lake Highlands. Zucca, et. al. (in press) conducted a seismic refraction study which shows a high-velocity anomaly at depths between .06 and 12 miles. The diameter of the anomaly is approximately 20 miles. Teleseismic relative travel-time residual studies by Evans (1982) reveals high velocity anomalies in the crust and upper mantle extending from very shallow depths to at least 100 kilometers beneath the volcano.

Leasing Status

Federal land in the KGRA is subject to competitive bid leasing procedures administered by the BLM. Surface management agencies in the area include the Klamath, Shasta, and Modoc National Forests. To date, over 32,400 acres of land within the recently expanded KGRA have been leased through competitive bidding.

Leaseholders are awarded the rights to explore for and develop geothermal resources on such lands for an initial period of ten years, with rights to renew for an additional forty years.

Companies which presently have leases in the KGRA are listed in Table 12. The exploration activities of these companies are described below in a following section.

The original KGRA was established in 1971, expanded once in 1974 and again in August, 1983. The original size of 33,336 acres has now reached 134,254 acres, an increase of over 300 percent. New KGRA lands include both lands where noncompetitive leases have been issued, and lands presently under lease application. Due to the apparently inconsistent issuance of noncompetitive leases since 1974 on some of these new KGRA lands it is expected that remonstrance hearings will be requested before the Board of Land Appeals of the U.S. Department of Interior. These hearings will allow lease applicants to appeal the BLM's KGRA expansion decision, which forces small lease applicants to bid against larger companies for competitive leases on land the smaller firms had already applied for on a noncompetitive basis. If the appeal is dropped, or if the BLM action is upheld by the Board of Land Appeals, the issue may go to the federal courts for resolution. Regardless of the outcome, further resource development at the Glass Mountain KGRA may be delayed at least one year and possibly as long as three years.

Table 12

FEDERAL LEASING ACTIVITY
IN THE
GLASS MOUNTAIN KGRA

December, 1983

Lessee	Acreage Leased	Range of Bid Prices Paid ($/acre)
Union Oil Co.	16,686[1]	25-505
Occidental Geothermal Inc.	7,080[2]	30-524
Anadarko Production Co.	5,020	195-207
China Lake Joint Venture	1,920	7.18
California Energy Co.	1,760	17.82
Total	32,466[3]	$208 Average

1 Includes 7,029 acres held jointly with Phillips Petroleum Co.

2 Includes 5,159 acres held jointly with Phillips Petroleum Co.

3 Most of the 870 acres of private land in the KGRA has been unitized but not leased.

Leasing activity at Glass Mountain results in revenues to Siskiyou County from several sources. California Assembly Bill 1905, enacted by the 1980 California Legislature, allows counties where geothermal resources occur on federal lands to receive 20% of the initial federal lease bids, as well as continuing rentals and royalties when development occurs. As indicated in Table 13, the County's share of bonus bids to date is $1,502,848 (to be disbursed to the County by the BLM in an initial 20% installment, followed by two annual payments of 40% each).

With annual rental fees of $2 per acre, the County will receive at least $12,966 per year for the leases issued to date. Under federal law this annual rental remains constant for the first five years of the lease, and is then escalated by $1 per acre per year thereafter. However, these latter escalated rental fees are usually reduced by the lessees' exploration expenses which are credited against rental fees. Therefore, although the rental escalation may raise the County's share from $0.40 per acre per year to $1.40 per acre per year in the tenth year (or $45,452/yr for the KGRA), it is likely that the escalated rate will be reduced substantially by crediting the lessees' exploration costs against it. From a conservative standpoint, the County should only plan on receiving $0.40 per acre per year until production begins, at which time it would begin to share in production royalties.

In terms of other local revenue the Siskiyou County Assessor collects property taxes on private lands within the County.

Table 13

GLASS MOUNTAIN KGRA LEASE REVENUES TO THE COUNTY

December, 1983

Date of Lease Sale	Acreage Leased	Total Bonus Bids ($)	County Share of Bonus ($)	Total Annual Rental[1] ($)	Annual County Share of Rental[1] ($)
2-18-82	25,437	6,584,372	1,316,874	50,874	10,175
3-24-83	7,029	929,872	185,974	14,058	2,812
	32,466	7,514,244	1,502,848	64,932	12,987

[1] Through 1991, but subject to change in the sixth year of leases.

However, the amount of private land in the Glass Mountain KGRA is negligible. Instead, another source of geothermal property tax income for Siskiyou County is based upon "possessory interest" in a property. This occurs when a private company leases state or federal land that was formerly tax-exempt. In this circumstance the developer is taxed on the value of the lease, and then on any wells as improvements. Geothermal leaseholds on federal lands, when sold on a bonus bid basis (the price paid to secure the lease), have been taxed in California as possessory interests whether or not there is any production of geothermal resource.

Depending upon the circumstances under which the winning bid was awarded, California county assessors have used the bonus bid price (or a portion thereof) as the value of the leasehold for taxation purposes. Geothermal leaseholds on private lands have not been taxed as possessory interests; they are taxed commencing only with discovery of the resource. Often, leases on private lands have not been recorded nor has there been a bonus bid price paid for the leases.

In March, 1983 the Siskiyou County Assessor added slightly over $7 million to the County tax base in geothermal possessory interests. This figure was expanded in July and again in November, 1983, resulting in a total assessed geothermal value of $8,122,387 for 1983. This added value could mean as much as $89,000 more in county tax revenues for the current fiscal year. Nearly all of the money is distributed to the County general

fund. Table 14 details the Assessor's current values for geothermal possessory interests.

Revenues from federal leases and possessory interests are projected through 1987 in Table 15 indicating the fiscal impacts to the County from geothermal leasing thus far. These projections are conservatively based on assumptions that no additional KGRA leases are issued, and that modest exploration drilling occurs each year. Should new leases be issued County revenues would increase accordingly. Revenue projections in the case of production for power generation are discussed in a following section.

Exploration Status

Of the six companies presently holding KGRA leases four have drilled exploratory holes to date. This drilling activity is summarized in Table 16 and shown in Map 5. Five temperature gradient wells, ranging in depth from 900 to 4,000 feet, were drilled in 1982 by Union, Occidental, and Phillips. These wells were drilled within the Medicine Lake caldera, or just outside the caldera's eastern rim. Bottom hole temperatures and average temperature gradient calculations of all five wells show that temperatures of at least 300°F can be economically reached with current drilling technology. In 1983 Union drilled a sixth gradient well to the southwest of the caldera rim, and plans to drill a deep test well during the summer of 1984.

Table 14

SISKIYOU COUNTY ASSESSOR'S VALUES FOR
GEOTHERMAL POSSESSORY INTERESTS

December, 1983

Date	Acreage	Assessor's Value	Potential Taxes @ 1.1%
March, 1983	44,679	$7,039,969	$77,440
July, 1983	7,029	1,015,188	11,167
November, 1983	9,079	67,230	740
TOTAL	60,787	$8,122,387	$89,347

Table 15

PROJECTED REVENUES FROM GEOTHERMAL LEASING[1]

December, 1983
($)

Year	AB 1905 Revenues[2]	PI Taxes[3]	Total
1983	313,000	89,000	402,000
1984	613,000	100,000	713,000
1985	613,000	115,000	728,000
1986	13,000	135,000	148,000
1987	13,000	160,000	173,000
TOTAL	1,565,000	599,000	2,164,000

[1] Assumes no additional KGRA lease sales and no resource production.

[2] Includes bid and rental revenues, regardless of development.

[3] Conservative well improvements and a tax rate of 1.1% assumed.

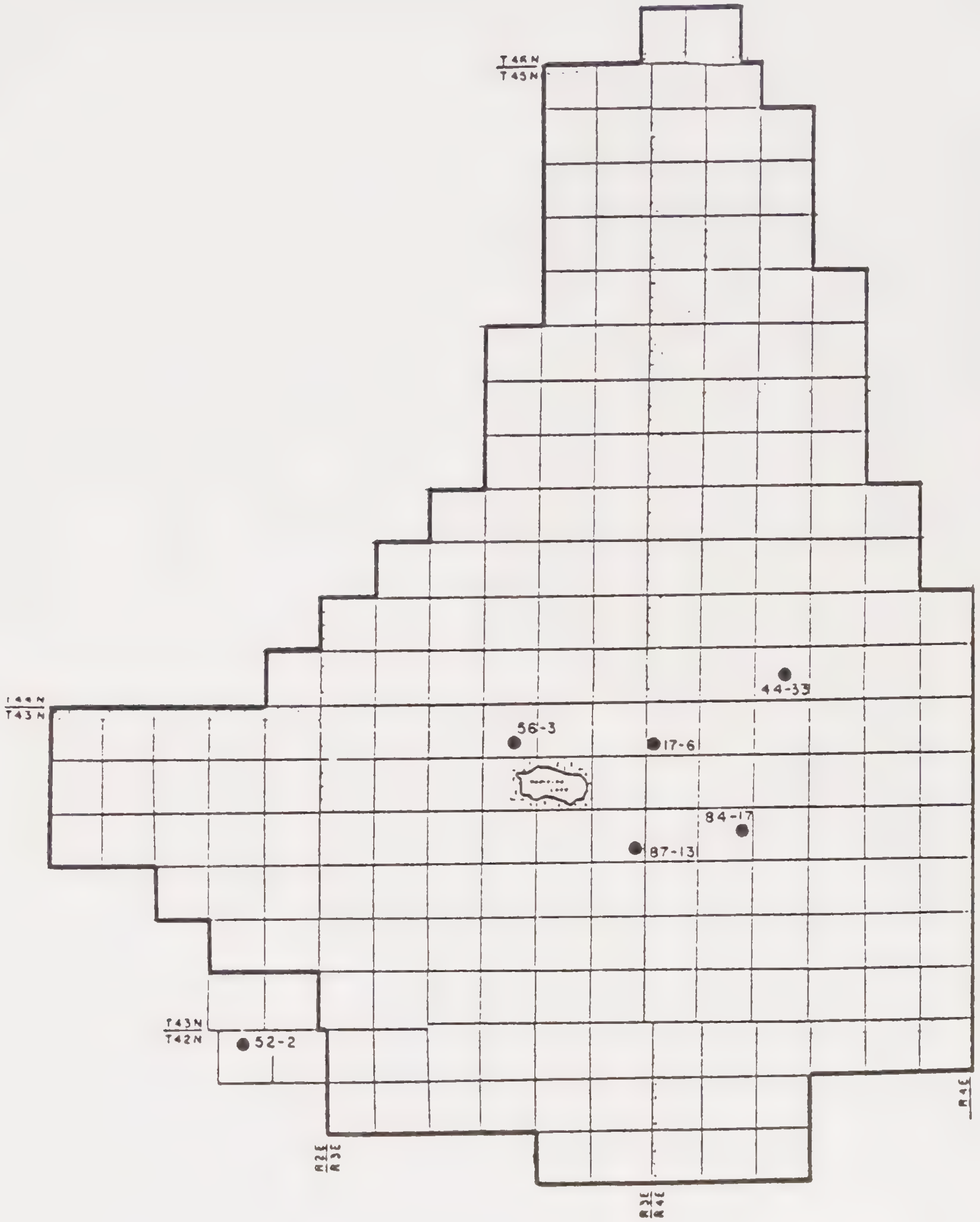
Table 16

EXPLORATION DRILLING IN THE GLASS MTN. KGRA

September, 1983

Well Number	Company	Location (MDBM)	Avg. Temp. Gradient (^{o}F/Mile)
44-33	Phillips/Oxy	33-44N-4E	Proprietary
84-17	Union	17-43N-4E	709.2
17-6	Oxy/Phillips	6-43N-4E	Proprietary
56-3	Union	3-43N-3E	307.4
87-13	Union	13-43N-3E	1,640.7
52-2	Union	2-42N-2E	Drilling

MAP 5: LOCATION OF EXPLORATION DRILLING IN THE GLASS MTN. KGRA



SCALE: ONE INCH EQUALS APPROXIMATELY 3.3 MILES

↑N

As exploration has continued the three largest companies, Union, Occidental, and Phillips, have unitized their interests under a federal procedure that allows common development without regard to ownership based on an allocation of costs and benefits. Union Oil Company has been designated as the lead unit operator for the area.

It is important to emphasize that, while exploration thus far appears to be promising, there still remains no certainty that a suitable commercial-grade high-temperature resource exists. Several years of continued exploration and testing remain to be accomplished before the resource's characteristics are definitively known. In the interim the County should closely monitor research and exploration activities as a means of preparing for probable development.

The Potential for Power Generation

If and when commercial-grade high-temperature resources are confirmed the County must then address the impacts of large-scale power generation. This type of development is distinguished from the small-scale wellhead generation described in a previous section, in that high-temperature power-plants are usually much larger (50 MW modules are common), requiring as many as 15-25 wells for a single plant that may occupy as much as 5-10 acres of land.

Large-scale geothermal power projects can employ 50-100 persons during construction, and 20-40 on a permanent operating basis. Clearly, this type of development will have significant impacts to the County in terms of physical changes to the landscape from drilling pads, collection pipelines, and the power plants themselves; from the demands put on local roads and public services; and the jobs created by construction and operation.

At this point it is premature to speculate on the particulars of such development, and therefore difficult to describe probable impacts. In the most general sense the following types of issues may arise if large-scale power development occurs in the Medicine Lake Highland:

- Roads. Production well drilling and power plant development will necessitate extensive use of heavy trucks, putting dramatically increased demands on roads in the resource area.

- Water supply. Large amounts of water could be required for plant cooling and related operational needs.

- Sewage disposal. The presence of construction and operating personnel will necessitate proper wastewater disposal.

- Solid waste disposal. Solid wastes from drilling, construction, and operations will require proper disposal.

- Drainage. Grading and excavations for roads and other facilities will put increasing importance on the adequacy of proper drainage and erosion control.

- Law enforcement and fire protection. The presence of construction activities and permanent operations will create ongoing needs for public safety services.

- Schools and general administrative services. Construction time for geothermal power plants can range over several years, and operating personnel become permanent residents in resource areas, creating new demands on schools and local governments' administrative services.

It must be reemphasized that the scope and extent of these impacts cannot be accurately gauged until much more is known about the area's high-temperature resources, and their suitability for power generation. However, in monitoring exploration activities the County should closely monitor likely impacts, and plan accordingly for necessary facilities and services. Fortunately, the County's leasing revenues and

production royalties will constitute a valuable fiscal capability for responding to such demands.

If large-scale resource production for power generation does occur in the future, the County's share of production royalties will be based on the commercial value of the resource and the amount of production. If the commercial value is assumed to be $31.68 per megawatt hour (which is comparable to current values at The Geysers), then a power plant operating 85% of the year would generate $4,718 per megawatt in County royalties (in 1983 dollars). Thus, a 55 MW plant could generate as much as $259,478 in annual royalties to the County. Potential revenues from power plants are projected in Table 17, indicating the production royalties and property taxes which would accrue to the County over and above the lease rentals and possessory interest revenues described earlier.

In terms of fiscal planning it is important to note that, while County property and possessory interest taxes may be expended as the County sees fit, the monies received from federal leasing and resource production are statutorily dedicated to further geothermal development or mitigation. The specific uses to which these federally-derived funds can be applied are described among the implementation measures of Section 6 of the Geothermal Element.

Table 17

POTENTIAL COUNTY REVENUES FROM LARGE-SCALE GEOTHERMAL POWER GENERATION
($)

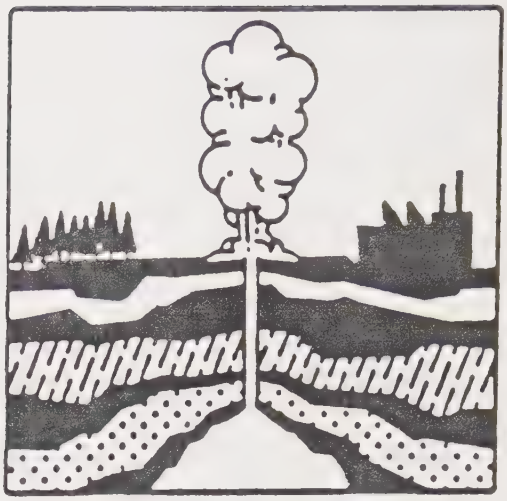
Power Plant Size	County Production Royalties[1]	County Property Taxes[2]	Total
10 MW	47,178	19,545	66,723
55 MW	259,478	107,500	366,978
110 MW	518,958	215,000	733,958

1 Assumes a federal royalty of 10% of the steam price, and a 20% County share of the federal royalty.

2 Based on comparable public utility values in Sonoma County.

It is strongly emphasized that high-temperature exploration is in its earliest stages, and there remains considerable work and successful resource confirmation to be accomplished before power development can be confidently expected. The time required for such large-scale development, if it occurs, is likely to be on the order of 5 to 10 years. This process could be delayed even further by the leasing protests which were described earlier.

5.



LAND-USE & ENVIRONMENTAL ISSUES

Overview

The land-use and environmental impacts of geothermal development vary dramatically from site to site, and from end-use to end-use. This site-specificity makes it difficult to generalize about environmental and land-use issues. For example, the environmental impacts of using 60°F ground water to operate a residential heat pump are vastly different than those associated with a 50 MW power plant using 350°F steam from 20 wells.

The discussion here will be limited to a broad review of common issues. These considerations may or may not be applicable to future projects in Siskiyou County, and their discussion here is intended only to illustrate the full range of environmental potentialities.

Given the general rule that environmental impacts decrease with resource temperatures, the fact that Siskiyou County's resource base is predominantly low- and moderate-temperature in character suggests that future geothermal development should not present major environmental problems. Clearly, the greatest potential for environmental impacts lies with the high-temperature resources that may be developed in the Medicine Lake Highland area.

Land-Use

The land-use impacts of geothermal development generally revolve around issues of compatibility. In many cases of low and moderate-temperature resource use, existing land-uses are simply retrofitted to resources that were determined to underlie the uses. However, in many cases the confirmation of a suitable resource raises the issue of what types of new land-uses can be introduced to the site in order to utilize the resource.

Given their widespread occurrence, low-temperature resources should be able to be developed for a variety of end-uses without being impeded by land-use compatibilities. In other words, heat pump utilization should be able to go forward without altering existing land-use patterns inasmuch as similar ground water resources will occur beneath residential, commercial, and agricultural areas.

On the other hand, the limited amount of information on moderate-temperature resources, which appear to be located in predominantly rural settings, makes it difficult to determine whether rural land-use designations will impede utilization. The major potential for conflict in this temperature range are instances of industrial processes which are proposed to be located in agricultural or other rural environs in order to take advantage of the resource. In these cases it may be necessary to apply stricter performance standards to the geothermal end-uses in order to assure compatibility with surrounding land-uses.

In the case of high-temperature resources, where they occur in forest or other natural areas there are clearly major land-use issues raised in terms of the compatibilities of power generation with surrounding natural qualities. Once again, after the policy decision of introducing power generation into a natural area has been made, land-use impacts can be mitigated by strict performance standards.

Air Quality

Impacts to air quality from geothermal development vary widely depending upon resource type and end-use. In the case of high-temperature power generation some release of hydrogen sulfide H_2S), ammonia (NH_3), carbon dioxide (CO_2), mercury, methane (CH_4), and other gases can be expected, with the severity of such emissions depending upon the gaseous content of the geothermal fluids, and the type of conversion facilities used in a particular power plant.

Alternately, air emissions from low- and moderate-temperature uses can be expected to be fewer in number and magnitude, particularly where closed-loop systems are used. Thus, the discussion here is related primarily to potential impacts from high-temperature resources.

The fluids in geothermal reservoirs may contain varying amounts of chemical species that do not condense during the heat

extraction process. The fractional content of such noncondensed gases varies widely, from 0.4 percent by weight at The Geysers, to 30 percent at Monte Amiata, Italy. The major constituent of this fraction is typically CO_2, with lesser amounts of NH_3, H_2S, and CH_4. Most extraction and utilization techniques will result in the release of these chemicals to the atmosphere unless control devices are used. An exception would be the use of a downhole pump to maintain pressure on the fluid through a heat exchanger and an injection well.

The release of CO_2 by geothermal power plants is significant only in the global context, and it is extremely unlikely that such plants will make significant contributions to the total flux of CO_2 to the atmosphere.

The release of H_2S is a substantial problem at The Geysers and has resulted in adverse reactions in downwind communities. This may not be as serious in other resource areas. The odor detection threshold of humans for H_2S is about 0.005 parts per million (ppm), and the California standard for ambient air is 0.030 ppm.

Effects of H_2S on vegetation have been demonstrated at concentrations in air of several ppm. The presently available evidence indicates that vegetation damage from this mechanism will not occur due to hydrothermal operations, but more research is needed to confirm this with additional vegetation species and to examine the synergistic action of H_2S with other pollutants. In the atmosphere, H_2S is slowly oxidized to sulfur dioxide (SO_2)

and sulfur peroxide (SO_4). The formation of sulfate and other sulfur-containing particulates is therefore certain. However, the slow conversion rate of H_2S to other sulfur compounds indicates that this will probably not present an actual problem because considerable dispersion will have occurred while conversion is taking place. In actuality, it is very unlikely that any new, commercial-scale power plant will be built in the United States without either H_2S abatement mechanisms or demonstrable proof that they are unnecessary due to the nature of the reservoir.

Many present geothermal power plants use direct-contact condensers. Because H_2S is soluble in water, about 70% of the H_2S is carried to the cooling tower with the condensate. Present environmental control technology consists of ducting the ejection off-gas to the cooling tower and adding an iron catalyst to the cooling water to oxidize H_2S to elemental sulfur. This method is not highly successful because of limited abatement, increased maintenance costs, and the need to dispose of large volumes of cooling tower sludge that contains unusable sulfur. New power plants sometimes have indirect contact condensers that will result in about 90% of the H_2S going to the off-gas ejector stream. This H_2S is then oxidized to commercial quality sulfur by the Stretford process.

Substantial amounts of NH_3 are also released at some resource sites, but the significance of this release appears to be minor.

NH_3 is frequently used as a plant fertilizer and is probably nontoxic to vegetation and mammals at expected concentrations. Dissolved NH_3 is toxic to aquatic life, but airborne releases should not be significant. There may be complex interactions of NH_3, sulfur compounds, and particulates that produce potentially harmful pollutants. This possibility deserves further analysis, but it is not presently considered to be an important issue.

Although not presumed to be a reaction of H_2S, vegetation stress has occurred at some resource sites in the immediate area of power plants. Presently available evidence indicates that this stress may be due to boron. This is a minor problem at The Geysers but could be of more importance at other reservoirs or with other adjacent land uses.

Mercury emission rates are generally inconsequential. Ambient air at The Geysers has the same concentration of mercury as was measured at background locations, although ambient air at the Cerro Prieto, Mexico resource area was above background levels. Additional measurements at other sites are needed to resolve this issue for local conditions.

The release of radon-222 and other radionuclides has also recently been measured at The Geysers. The average emission rate of radon-222 is 130 nanocuries/kwh. Concentrations in ambient air of the short-lived radon-daughters at The Geysers are within the range of concentrations measured at background locations. Levels of other naturally occurring radionuclides in The Geysers

were also within normal background levels. Measurements of radon in fluids at other sites indicates that the release of radionuclides should not be an important issue. However, confirmatory measurements of emission rates and ambient concentrations in the vicinity of new uses should be made.

Airborne effluents in the form of cooling system drift are also expected at power plants. The magnitude of this potential problem is very dependent upon technological options. By far the largest of the airborne emissions from geothermal power plants will be water vapor. Because the thermodynamic efficiency of such powerplants is low, the release rate per unit of energy produced is higher than for other conventional power plants. In some locations, this water vapor release may result in local fogging and icing conditions.

Water Quality

The management of spent geothermal fluids is one of the most important issues confronting development at many locations, although some fluids are so pure they have been used for domestic consumption, irrigation, and other beneficial uses. Some fluids can be very saline, however, and discharges to surface waters would not be desirable in this case. The preferred disposal method is to inject the spent fluids back into the geothermal reservoir. Injection of excess steam condensate has been carried out successfully for several years at The Geysers. Similar success has occurred in the Klamath Falls area, where moderate-

temperature fluids have been injected for many years without adverse impacts.

It may be realistic, therefore, to assume that plants utilizing liquid-dominated reservoirs can be operated over long periods with no intentional release of spent fluids to surface waters or into underground aquifers of beneficial use. Research studies and long-term monitoring at selected sites are necessary, however, to ensure that unintentional contaminations do not occur. The accidental release of geothermal fluids could, in some areas, have a serious impact on aquatic and terrestrial ecosystems.

There may also be problems with waterborne effluents during the well drilling process. These problems are not unique to geothermal energy, but contaminating events have occurred on several occasions at geothermal sites. These releases are of an accidental nature and are already covered by drilling regulations. It is suggested that improved enforcement procedures could eliminate or greatly reduce such releases in the future.

Another potentially major issue involving waterborne effluents concerns power plant cooling systems. There are many options for the design of such systems, but the options may be severely limited by available water quantity and quality, and by cost. Most practical cooling systems will probably require the

discharge of cooling water blowdown. This water will be brackish and may contain additives or geothermal fluid carryover if steam condensate is used as makeup water. For hydrothermal systems it may be possible to inject this blowdown with the spent fluids, but there are questions as to whether the two fluids can be mixed without worsening scaling problems in some liquid-dominated systems. The cooling system design of any proposed plant must be evaluated carefully for possible effects on ecosystems, both by the dissolved solids and by the thermal discharge.

Noise

Major noise-producing events are drill rig operations, venting during high-temperature well completion, and the discharge of steam when power plants are shut down. These problems have been reduced by the use of better mufflers and the installation of cross-ties between steamlines so that it is not necessary to release as much steam to the atmosphere when power units are shut down.

The noise of construction activities and operations at power plant sites can also be expected to have certain impacts on surrounding wildlife. Studies at The Geysers have indicated that these impacts are not notably adverse, suggesting that, unless a species is unusually endangered, noise is not a major factor with wildlife.

The noise issue is expected to be much less important at liquid-dominated or lower temperature resource sites. In these cases pressures would be lower, and noise levels associated with well tests much lower than at The Geysers. Measurement programs will be necessary, however, and mitigation measures perhaps required.

Subsidence

The removal of large quantities of fluid from a geologic formation may result in subsidence, or sinking of the land. Such subsidence has been common following the withdrawal of water and oil. It has also been observed at the Wairakei, New Zealand, geothermal power plant where a maximum rate of subsidence of about 1.3 feet/year has been measured. However, the injection of spent geothermal fluids back into the formation is not done at Wairakei; the spent fluids are discharged to surface waters.

It is hoped that the injection of spent fluids back into the reservoir will not only solve the liquid waste problem but will also eliminate or mitigate the subsidence problem. However, this is not known with certainty; localized sinking around production wells and uplifting around injection wells may still occur.

A better understanding of geothermal reservoirs and the factors that control subsidence may eventually lead to the development of management strategies that can completely control subsidence. It is necessary to assess the problem by acquiring precise leveling data to measure actual rates of subsidence at geothermal

facilities. Baseline data are also important because many geothermal sites can be expected to be undergoing tectonic subsidence. For example, a naturally occurring subsidence of 13 centimeters was observed in the northern end of Imperial Valley during a recent 2-year period.

Induced Seismicity

Many geothermal reservoirs are located in regions with a high frequency of naturally occurring seismic events. A significant issue is whether the withdrawal and injection of geothermal fluids may enhance the rate of microseismic events, or even trigger a major earth movement. Although some studies implicate the process of reservoir cooling, the most likely cause of induced seismicity is believed to be the injection process. Studies in Colorado have demonstrated that the frequency of microseismic events is increased as a result of the high-pressure injection of fluids.

It is not known what pressures will be required to maintain the injection of spent fluids over long periods of time at liquid-dominated sites, but field trials indicate that the pressures may be well below those demonstrated to cause induced seismicity. The possible lubrication of a major fault and the resultant triggering of a major earthquake is another unresolved issue; careful site selection to avoid major faults should alleviate this concern.

Because these potential effects are unresolved, detailed microseismic studies should be conducted at prospective sites for large-scale development. Baseline data on the frequency of seismic events and the depth at which they occur will provide valuable information in distinguishing between naturally occurring and induced events.

Water Use

Generally low- and moderate-temperature applications do not require exogenous source of water for operational purposes. However, nearly all methods of geothermal power generation do require cooling water for heat rejection systems. In semi-arid regions conflicts over the allocation of limited water resources can be expected.

Fish and Wildlife/Vegetation

Any human activity, including the exploration for and the development of geothermal reservoirs, can put pressure upon native flora and fauna. Because geothermal energy is extracted as heat, it cannot be transported over long distances but must be utilized close to the location where it is found. The most significant issues are expected to arise when geothermal resources are located on or adjacent to areas designated as critical habitat areas. Such issues should be expected not only at well sites and power plants, but for powerline corridors as well. It is therefore essential that information concerning the

presence of endangered and threatened species be obtained prior to development.

In assessing the environmental effects of geothermal development in the Medicine Lake Highland area, the USFS and BLM have identified the following species as being potentially impacted: bald eagle, peregrine falcon, wolverine, golden eagle, prairie falcon, shasta salamander, goshawk, osprey, and spotted owl. In addition to these species, a wide variety of mammals, birds, and fish inhabit the area. There are also a large variety of sensitive plants in the vicinity.

It is important to note, however, that proximity to critical habitat areas may not necessarily preclude geothermal development. In fact, there have been several examples in the western United States of habitats being adequately protected by buffer zones which have allowed geothermal development to proceed in the vicinity. As with most other environmental issues, this must be evaluated on a case-by-case basis, and mitigative measures employed accordingly.

<u>Socio-Economics</u>

Many social, economic, cultural, and political issues may arise as geothermal energy is developed. In some cases resource development may be opposed because of threats to rural or recreational values in an area. Where resources occur in

agricultural areas competition may develop between farming and ranching activities and geothermal uses. Alternatively, the development of geothermal resources can provide many positive social and economic benefits. Tax bases can be broadened and the economy in affected communities diversified. Early planning with affected communities could be effective in developing appropriate manpower resources so that positive steps can be taken to reduce local unemployment.

In general, geothermal projects occur in a phased manner with exploration leading to the construction of power plants or direct-uses in modest increments. This type of phased development should not result, therefore, in immediately overwhelming socio-economic impacts.

Safety and Health

The issues of occupational safety and health appear to be notable only for high-temperature applications, where high pressures, flammable fluids, and corrosive chemicals are examples of circumstances calling for prudent safety practices. To date, because of its relative youth the geothermal industry does not have a clear picture of occupational health problems associated with geothermal power generation; however, there is no evidence yet suggesting inordinately high risks of occupational disease.

Health research to date indicates that the greatest hazards from high-temperature resources are hydrogen sulfide, and particulate

sulfate from the atmospheric oxidation of hydrogen sulfide, benzene, mercury, and radon. As discussed earlier, baseline research and monitoring of these constituents should accompany any future large-scale development.

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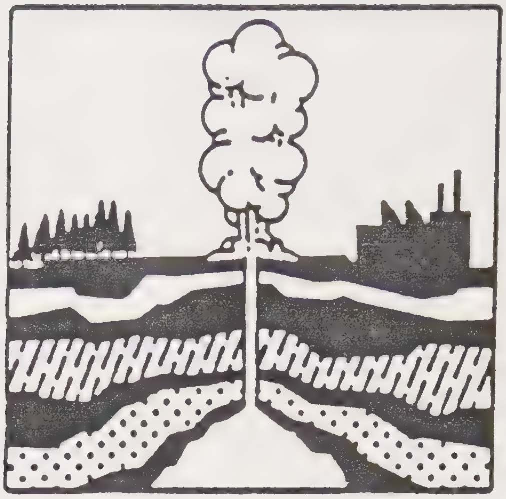

POLICIES & IMPLEMENTATION MEASURES

Overview

Having assessed the nature and occurrence of geothermal resources in the County, and having evaluated the likely methods of their utilization and the impacts associated with such use, the final component of the Geothermal Element is an articulation of County policies and implementation measures for guiding geothermal development. Such policies and implementation measures are premised on the following roles which the County has in the geothermal development process:

- Land-use planning and permitting.
- Environmental impact review.
- Support for local economic development programs.
- Authority to regulate well drilling and geothermal facility siting, construction, and operations.
- Authority to directly undertake exploration activities.
- Authority to directly construct and operate geothermal facilities.

Thus, in the future the County may become either a regulator, promoter, or user of geothermal energy; or any combination of these roles. The current status of geothermal development in the County suggests that the following courses of action may

constitute the most logical position for the County in the near future:

- High-temperature power development prospects appear limited to the Medicine Lake Highland area, which is subject to extensive federal oversight. However, the County has major interests at stake in such development and for the forseeable future should closely monitor federal and private sector activities.

- Moderate-temperature resources appear to be limited to the northern basins of the Modoc Plateau. However, there is very little information available to characterize this temperature range, and in the future the County should consider conducting advanced resource assessment to increase the knowledge about these resources. This type of resource is considered important for the County in terms of its suitability for various agricultural and industrial processes that hold the greatest potential for economic diversification.

- Low-temperature resources appear to be widespread throughout the County, and appear to offer the

most immediate opportunity for beneficial use and economic development. It is notable that this area does not presently receive substantive regulatory attention, and in the future the County should consider some form of local oversight to optimize low-temperature benefits and assure ground water protection for non-geothermal uses.

- The County and other local government agencies have immediate opportunities to begin using low-temperature resources in conjunction with water-source heat pumps, and as facility rennovation or construction comes about these agencies should evaluate the site-specific feasibility of using geothermal heat pumps for heating and cooling.

Given the County's various roles in the geothermal development process, and the foregoing conclusions about the state of the resource in the County today, the following sections list recommended policies and implementation measures deemed appropriate to these circumstances. It is important to note that the status and implications of geothermal energy in the County will change continuously over time as exploration and utilization progresses. Therefore, it will be necessary to periodically review and amend the Geothermal Element to accommodate changing conditions and local goals.

Policies

In order to guide geothermal development in Siskiyou County the following policies recommended for adoption:

Lead County Department

1. The Planning Department is designated as the County department with primary responsibility for geothermal energy matters. This responsibility shall include monitoring of geothermal development in the County; provision of assistance and information to persons interested in such development; advice to the Board of Supervisors and Planning Commission regarding geothermal matters related to the County; and administration of any future geothermal regulations adopted by the County, except for those state air quality regulations administered by the Siskiyou Air Pollution Control District.

2. The Board of Supervisors may assign other geothermal responsibilities to other County departments as deemed appropriate.

Intergovernmental Coordination

3. The County shall encourage the formulation of federal and state land and resource management policies which are consistent with the County's geothermal policies.

In this regard the County shall endeavor to become an equal partner with the federal and state governments in determining the future of geothermal energy in the County.

4. In view of the multiplicity of governmental jurisdiction over geothermal resources, the County shall seek close coordination with all affected local, state, and federal agencies. In this regard the Planning Department shall maintain regular communications with federal and state agencies that are exercising geothermal responsibilities in the County, and shall keep local agencies informed of federal and state actions accordingly.

Public Involvement

5. The Planning Department shall ensure that citizens are given ample opportunity to be involved in all phases of geothermal planning and development that occur in the County. This public involvement program shall provide for continuity of citizen participation, and for information that enables citizens to identify and comprehend geothermal issues.

6. Federal and state agencies exercising geothermal responsibilities in the County shall be expected and

encouraged to make use of the County's public involvement program whenever appropriate.

County Regulatory Involvement

7. Given the present status of geothermal energy in the County it is believed that the public interest is sufficiently protected without establishment of new County regulations governing geothermal development. This policy is based on the fact that the character of low- and moderate-temperature resources remains to be assessed further before development potentials can be definitely identified; and that high-temperature resources appear to be limited to federal lands which are already subject to extensive federal and state regulations, including state air quality standards administered by the Siskiyou Air Pollution Control District.

8. Notwithstanding Policy 7, the County shall closely monitor geothermal development to determine if and when new County regulations are warranted for the protection of local interests. In particular, the County is cognizant of the potential need for strengthened ground water management practices if the use of low-temperature resources is to be optimized. Further, in regard to high-temperature resources the County is cognizant of its ability to obtain exploratory drilling

and power plant siting authority from the California Division of Oil & Gas, and the California Energy Commission respectively.

9. If and when County geothermal regulations are promulgated, the County shall seek to avoid duplication of other agency rules wherever possible; and shall endeavor to see that any County geothermal standards are as consistent with other agency standards as practical.

Resource Assessment

10. In order to identify and protect the undefined values of its geothermal resources, the County shall support continued resource assessment activities by both public and private sectors. In this regard, the Planning Department shall monitor such activities and collect additional resource data wherever possible for inclusion in the Geothermal Element during updates or amendments.

11. In recognition of the public benefit derived from greater resource knowledge, the County may undertake its own resource assessment activities where such work is expected to stimulate further exploration and resource end-use. The results of County-sponsored resource assessment will be given the widest possible

dissemination in order to facilitate further geothermal development consistent with County policies.

Resource Utilization

12. The County supports utilization of geothermal resources, either with heat pumps, direct applications, or for purposes of generating power. However, such support is conditioned on a determination that the proposed use can be developed in a timely, orderly, and environmentally-sound manner, and that adequate protection of the resource is provided so as to ensure its continued availability and productivity over time.

13. When County facilities are to be rennovated or newly constructed consideration shall be given to the use of geothermal resources in these facilities when such use is technically and economically advantageous. The County shall encourage other local agencies to conduct similar geothermal evaluations during their facility planning processes.

Economic Development

14. The County's support for geothermal development shall be closely coordinated with the County's economic development goals. The County believes that its geothermal resources can offer a significant

comparative advantage to business and industry, and it shall support geothermal projects that serve to retain or create employment opportunities in the County.

Land-Use

15. The County recognizes that if utilization of geothermal resources is to be optimized the designation of land-uses for areas overlying geothermal resources must accommodate those uses to which geothermal energy can be applied. In this regard the County shall incorporate geothermal utilization as a determinant in land-use planning; and, where feasible, shall allow sufficient flexibility in permitted uses to enable consideration of geothermal applications if and when suitable resources are confirmed in an area.

16. Notwithstanding Policy 15, geothermal end-uses shall be permitted only where their compatibility with surrounding land-uses can be demonstrated with certainty.

Environmental Protection

17. In all cases the County's support for geothermal development and utilization shall be conditioned upon satisfactory evidence that sufficient environmental safeguards are provided. Environmental concerns of the

County shall include, but not be limited to: air quality, water quality, noise, subsidence, induced seismicity, water consumption, fish and wildlife, vegetation, historic and cultural resources, visual and scenic qualities, socio-economics and occupational safety and health. In cases where important fish and wildlife resources could be degraded by development on federal lands, the County shall encourage the appropriate land management agency to utilize No Surface Occupancy stipulations to protect habitat areas. On private and state lands the County shall not permit development in critical habitat areas, and in all cases shall not permit development within 1,000 feet of surface waters and wetlands.

Public Facilities and Services

18. In addition to Policy 17, the County's support for geothermal development and utilization shall also be conditioned upon a lack of adverse impacts to local public facilities and services. In this regard, the County's concerns shall include, but not be limited to: roads, drainage, schools, law enforcement, fire protection, water supply, sewage disposal, solid waste disposal, and general administrative services.

19. The Planning Department, in consultation with the Public Works Department, shall monitor geothermal

activities in order to forecast impacts to public facilities and services; and shall prepare capital improvement or related plans accordingly so as to support geothermal development in a timely and orderly manner with a level of facilities and services appropriate to such development.

Fiscal Responsibilities

20. In recognition of the specialized demands that may be placed on the County by geothermal developers, and the benefits that will accrue to such developers from County services and facilities, the County shall require said developers to defray County expenses associated with processing geothermal permit requests, conducting related studies or monitoring programs, or providing services directly required by a geothermal project. This Policy shall extend to any public entities engaged in geothermal development.

Implementation Measures

Having established policies for guiding geothermal development, this section discusses various measures which can be used by the County to actually implement the policies. The measures discussed here are preliminary suggestions, and as the Geothermal Element and its policies are refined over time the County's implementation strategy will also necessarily need revision.

Implementation measures are described according to their corresponding policy topic as follows:

Planning Department Capability-Building

- As the County's lead department for geothermal matters the Planning Department will need to assign specific staff responsibilities for geothermal matters.

- In order to perform adequate monitoring and evaluation of geothermal activities the staff will require appropriate training and professional development in technical geothermal subjects.

- The Department should join appropriate geothermal professional organizations, e.g. the Geothermal Resources Council, and participate regularly in professional and educational programs.

Intergovernmental Coordination

- The County's present coordination agreement with the USFS is limited to mining and reclamation. This should be supplemented by a new agreement, which includes the BLM as well as USFS, devoted specifically to geothermal development in the County. The purpose of such a geothermal

coordination agreement would be to clearly establish the County's desire to be thoroughly involved in all federal actions related to resources within the County, and to provide for specific procedures assuring such coordination. Given the continuing exploration activity in the Medicine Lake Highland, this should be a relatively high priority implementation measure.

Public Involvement

- The Planning Department should place copies of the Geothermal Element at libraries and other public facilities throughout the County to assure the widest possible dissemination of its contents.

- The Planning Department should distribute copies of the two citizen guidebooks which have been prepared concurrently with the Geothermal Element, to provide citizens with detailed information on resource characteristics and utilization techniques.

- The Planning Department should hold periodic public briefings for the Board of Supervisors and Planning Commission on the status of geothermal activities, thereby giving the local media opportunities to report on current developments.

County Regulations

- The Planning Department should evaluate the need for two types of County regulations: first, low-temperature measures aimed at ground water protection and heat pump utilization; and second, higher temperature measures concerned with large-scale drilling and direct and/or power end-uses. The Planning Department should survey other local governments that have adopted such regulations to document their experiences and determine the applicability of such measures to Siskiyou County conditions.

Resource Assessment

- Further resource assessment is needed to characterize the County's ground water as a low-temperature resource. This assessment work should be focused in Scott and Shasta Valleys, and in the northern basins of the Modoc Plateau. The objective of such assessment work should be further identification of resources suitable for heat pump use, and development of management practices that assure protection and conservation of ground water in general. Specific activities that should be considered include:

- Detailed hydrogeologic investigation of ground water conditions in Shasta and Scott Valleys, and the northern Modoc basins (measurement and sampling of existing wells).

- Establishment of a computerized data base of well logs.

- Establishment of a County permit program to monitor future development.

- Further assessment work should also be directed towards moderate-temperature resources in the northern Modoc basins. The objectives of this work should be resource confirmation that leads to economic improvement or growth in the area. Specific activities should include:

  - Detailed investigation of existing characteristics (measuring and sampling of existing wells and springs).

  - Geophysical and geochemical analyses of the area.

  - Temperature gradient drilling at favorable resource sites.

  - Reservoir testing and modeling.

Economic Development

- The Planning Department should work with the Siskiyou County Private Industry Council to ensure that geothermal energy is recognized as one of the County's comparative advantages for business, and that prospective industries are made aware of local opportunities for geothermal utilization.

- The County should perform resource assessment at industrial sites so as to enable the marketing of such sites on the basis of a confirmed geothermal potential. Detailed investigations should be made at the eleven major industrial sites along the Interstate 5 corridor.

Land-Use Planning

- The other elements of the General Plan should be reviewed to assure internal consistency between the Geothermal Element and the other elements. A preliminary review indicates no major potential conflicts between elements.

- The zoning ordinance should be amended to accomplish the following: 1) add oversight of geothermal development as a purpose; 2) define

geothermal activities, e.g. drilling, end-uses; and 3) designate which zones geothermal activities are to be permitted in, and under what conditions.

Environmental Protection

- The Planning Department should formulate a program for assembling baseline data in resource areas. Given sufficient advance planning and preparation, with baseline data already being collected future development should therefore not be unnecessarily delayed by environmental review.

- The Planning Department should review applicable federal and state environmental quality standards to assure that such standards satisfy the intent the County geothermal policies.

Public Facilities and Services

- The Planning Department should survey other local governments that have experienced substantial geothermal development to document the nature and extent of facility and service impacts from such development. The results of this survey should be used to gauge prospective impacts in Siskiyou County, and enable facility and service planning to proceed accordingly.

Fiscal Resources for Implementation

As discussed in Section 4 of the Geothermal Element, the County is receiving a portion of the federal geothermal leases issued in the Glass Mtn. KGRA. This revenue will continue over the life of the leases, which could extend up to 40 years. To date the County is entitled to approximately $1.5 million from the initial lease bids, and approximately $13,000 annually over the life of the leases. This revenue will increase dramatically if and when new leases are issued, and when production of resources occur.

The California Public Resources Code (Chapter 6, Section 3800, Division 3) defines eleven categories of eligible expenditures for these funds. Technically, the statute distinguishes five categories where geothermal development "is contemplated," and six categories in areas where resources are "being developed or are in production." The California Energy Commission, which disburses these funds, has determined that "development" is already underway in Siskiyou County as a result of the exploration holes drilled in the Glass Mtn. KGRA. Therefore, all eleven categories are available to the County.

The eleven categories are listed below along with preliminary recommendations for expenditures in Siskiyou County. In reviewing the expenditure categories it is important to note that only two of them (No.'s 6 and 9) stipulate a direct link between geothermal development and the subsequent expenditure. In all other categories expenditures do not need to be directly tied,

either geographically or programatically, to a given geothermal project, but rather need only be "related" to geothermal energy. Thus, inasmuch as Siskiyou County is underlain by low-temperature heat pump resources, expenditures made anywhere in the County can conceivably be "related" to geothermal energy. Moreover, except for Category 9, capital improvements need not be made in the vicinity of geothermal projects (particularly those under Category 11).

The eleven categories are reviewed below using the statutory language in capitalized titles, followed by suggestions for permissible activities:

1. RESOURCE ASSESSMENT

   a. Advanced assessment of low- and moderate-temperature resources in Shasta and Scott Valleys, and the northern Modoc basins.

   b. Ground water studies, testing, and monitoring.

2. REGULATORY COMPLIANCE

   a. Partial funding of Planning Department and Air Pollution Control District staff salaries and equipment.

3. ADOPTION OF MITIGATIVE REGULATIONS

a. Research and preparation of County geothermal regulations; research and preparation for assuming lead agency status.

4. DATA COLLECTION AND ENVIRONMENTAL MONITORING

a. Improvement of County base mapping.

b. Establishment of micro computer-based resource information system.

c. Air quality studies.

5. GENERAL PLAN AND RELATED DOCUMENTS

a. Upgrading of General Plan elements and implementing ordinances where needed.

6. DIRECT GEOTHERMAL ADMINISTRATIVE COSTS

a. Air quality analysis and permit processing.

7. GEOTHERMAL FACILITY INSPECTION

a. Inspection of drilling sites for air quality compliance.

8. MITIGATIVE CAPITAL IMPROVEMENTS IN GEOTHERMAL AREAS

a. Not yet applicable.

9. SERVICE AND FACILITY IMPROVEMENTS RELATED TO GEOTHERMAL

a. One-stop permit center.

b. Expanded road maintenance in the eastern County.

c. Expansion of other services in the eastern County as needed.

10. DIRECT-USE AND ELECTRICAL DEMONSTRATION PROJECTS

a. Feasibility study for retrofitting the Courthouse and other County facilities.

b. Feasibility studies for other local government facilities.

c. Feasibility study of County-operated wellhead generation.

11. NATURAL RESOURCE CAPITAL IMPROVEMENTS

a. Miscellaneous improvements in County parks, solid waste facilities, drainage facilities, water systems, etc.

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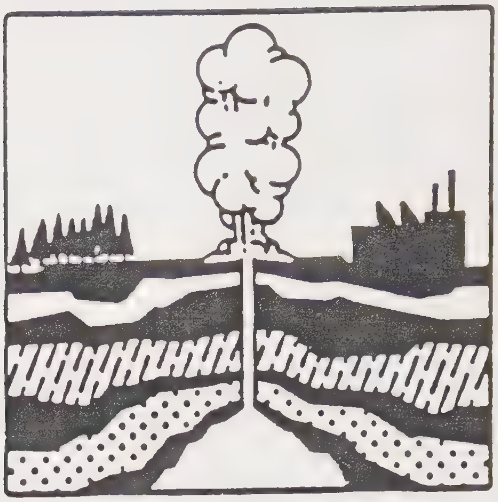

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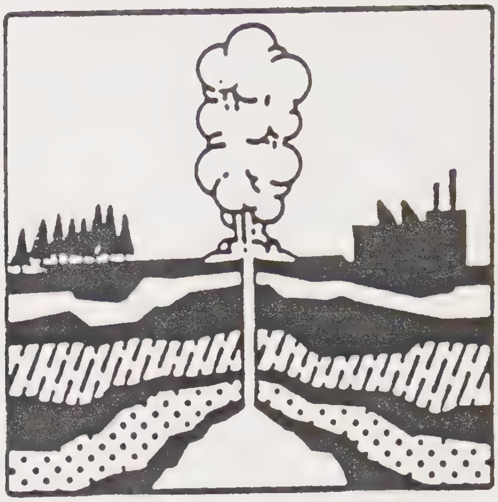

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Each bibliographic citation is accompanied with an abbreviation for the publication's primary locational focus and subject matter. These abbreviations are defined as follows:

Location Abbreviation

A	Major geomorphic province
(a)	Significant subprovince
R	Regional
K	Klamath Mountains
SCV	Scott Valley
SHV	Shasta Valley
C	Cascades
ML	Medicine Lake Highland
M	Modoc Plateau
NB	Northern Modoc Basins
T	Topical
?	Undetermined

Subject Abbreviation

M	Mining and minerals
GG	General Geology
V	Volcanism
GEO	Geothermal
GW	Groundwater
E	Seismicity
GP	Geophysics
H	Hydrology

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